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I. ANIMAL DEPRAVITY.

> "Selten habt ihr mich verstanden,
> Selter auch verstand ich euch;
> Nur wenn wir im Koth uns fanden
> Da erkannten wir uns gleich."
>
> HEINE.

"IT is of no use to talk about reason," said a friend with whom we had been discussing the subject;—"If you wish to establish man's kinship with brutes, you must prove that they, too, are capable of vice, his imagined prerogative." We could not deny that this was sound counsel. In sermons and platform-orations and in leading articles man declaims, indeed, in favour of "virtue." But listen to him in his more confidential moments when he flings aside his disguises. You will find that he then pronounces such of his own species as make some apparent approach to this official standard "nincompoops or hypocrites." The faint praise with which he damns goodness but half hides the underlying sneer. Scarcely can you, in the German language, speak of a man in terms which convey a lower estimate of his abilities or his energies than when you call him "eine gute Haut," or "eine gute Seele." On the contrary "ein böser Kerl" is always understood to be clever and plucky. Even the virtuous English, senior wranglers in the school of hypocrisy, have similar idioms. "A good boy," "a moral young man," "a very good sort of fellow," "a man with no harm in him," are terms used by no means in a complimentary sense. Of all the literary diseases of the day "goody-goodyism" is the one most despised by cultivated men of the world. On the other hand, when a woman is particularly well pleased with her lover does she not always call him a "naughty man?" Do all these phrases spring from a secret conviction that human vices are restrained less by conscience and high principle than by weakness or cowardice? Does the world suspect that the good man has often merely "nothing in him?"

But when we attempt to treat of the morals of brutes, in order to find whether in that region lies the much talked-of but evanescent boundary-line—when we seek to show that vice is, after all, not man's exclusive attribute, we are met at once with the objection—" Animals have, and can have, no moral life, as is man. They have no perception of right and wrong, but simply follow their propensities, and obey the laws of their being, from which, indeed, they have no power to depart." * This is, I think, a tolerably fair specimen of the language which *demi-savants* habitually use when treating of the lower animals. " The kingdoms of freedom and of nature " is an antithesis common in their mouths,—the " kingdom of freedom," forsooth, signifying mankind! It is, of course, exceedingly convenient to have some imaginary *a priori* reason which renders any appeal to facts superfluous, or rather altogether impertinent. Being neither lunatics, metaphysicians, Calvinists, nor fallen angels, † we shall not enlarge upon " freedom ;" we will merely declare that if men's vaunted freedom relates to *action* it is shared by the gorilla. He is perfectly free to rise up or sit down, to come or go, to crack a nut, or to crush the skull of a " man and a brother," just as he may think proper. That he is " free " to love or to hate ‡ to fear or hope, to believe or disbelieve, or in short to experience any emotion, passion, feeling, sentiment, or frame of mind, we deny, just as we deny it of man. Now to the more immediate question.

In the first place we must judge every animal from what may be called its own point of view, not with reference to man and his notions of advantage or convenience. He calls the wolf and the tiger cruel, the viper malignant, and the spider treacherous. This is idle talk. The wolf can only subsist upon animal food, and is no more to be censured for devouring the lamb,—for which he may further plead man's conduct in precedent—than is the lamb for devouring grass. Why, moreover, should the vegetarian,—brute or human—presume to denounce the flesh-eater as cruel ? Have plants no rights ? Are we sure that, if they could be consulted, they would consent to be plucked and eaten ? They have, it is true, no demonstrable nervous system. But in view of the manifold ways by which in creation we see one and the same end accomplished,—in view, too, of the facts on vegetal sensitiveness now ascertained—can we accept this as conclusive evidence? A Society for the Emancipation of Vegetables should be formed at once and begin soliciting subscriptions. Such a movement would not be more unreasonable than certain other phases of modern British humanitarianism.

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* " Animals, as a rule, do no more than follow their natural instincts." Rev. G. Henslow, " Theory of Evolution of Living Beings."

† Milton most happily represents his devils discussing on free-will.

‡ " It Lies not in our Power to Love or Hate."—Marlowe.

It is a great mistake to suppose that herbivorous animals are necessarily milder than the carnivora. The contrary is often the case. The flesh-eater attacks and kills for food. The grass-eater, *e.g* the Cape Buffalo, and even the domestic bull indulges in wanton outrages and "unprovoked assaults." His tendency to these peculiarly English offences is, perhaps, the reason why he has been, under the name of John Bull, chosen as the type of the nation.

The true question is, Does a brute, like man, ever violate "the laws of its own nature?" If it is found incapable of departing, whether to the right hand or the left, from one fixed line, we must then pronounce it, according to the commonly received notion, alike incapable of vice and of virtue, void indeed of moral life, in as far as this is deemed to be dependent upon choice.* But if it can deviate more or less from the norm of its existence, and especially if by such transgression it entails suffering upon itself and others, we are then, we submit, warranted in regarding its actions as morally good or evil,—good in as far as it conforms to the laws of its being; evil when it goes astray.

We may then judge it, just as man judges his own actions and those of his fellows; the full likeness of the cases justifying us in drawing like conclusions. It will be admitted that "brutes" have wills of their own which vary in intensity among individuals of any given species in the same manner as in man, if not to the same extent. Among domestic animals there are some, which, in spite of kicks and cuffs and general maltreatment, persevere in their own way. Such creatures, man taking, as usual, himself for the law of the universe, pronounces "vicious." There are others, again, which, under all circumstances, unhesitatingly submit their will to his, and these he praises.

The same method of judging, by the way, is applied to dependents and children. A child deficient in vital power implicitly obeys his parents and "betters" from want of energy to dispute their commands. He is, accordingly, held up to general admiration; his early death is pronounced a "mysterious dispensation of Providence," and his virtues and precocity are duly chronicled in a tract. On the contrary, the healthy and vigorous child, full of life and action, is apt to rebel against authority. It is, therefore, set down as a tiny incarnation of evil, and if it finds its way at all into a pretty story-book, is made to serve as an awful warning for the rising generation. There is wonderful virtue in listlessness, and in impotence lies an inconceivable amount of purity. Perhaps if we take the latter term in its modern cant sense the two may be regarded as practically synonymous.

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* If there were no evil, would there be also no good? If all matter were absolutely transparent and incapable of throwing a shadow, would light cease to exist?

The existence of a will, capable of acting at times in defiance of circumstances, is as clearly manifest in the horse, the ass, and the pig as in man himself, though in the three former it is little appreciated. Strange that what in animals is branded as stupidity should in man be deemed almost divine.

Were brutes devoid of freedom, unable to choose between two lines of conduct, we should find them in all cases simply obedient to their propensities, and intent only upon immediate gratification without any regard to ulterior consequences. Were such the case, for man to train them would be an impossibility. Yet we know that dogs, cats, hawks, &c., are trained to conduct quite different from their natural inclinations. A cat, though one of the most self-willed of animals, can be taught to abstain from molesting chickens, pigeons, and cage-birds, or from stealing, scratching furniture, &c. A dog can be brought to point to a covey of partridges instead of obeying his natural impulse to rush forward and endeavour to seize them. The following case is very significant: —" A fine terrier in the possession of a surgeon at Whitehaven, about three weeks ago exhibited its sagacity in a rather amusing manner. It came into the kitchen and began plucking the servant by the gown, and in spite of repeated rebuffs it perseveringly continued in its purpose. The mistress of the house, hearing the noise, came down to inquire the cause, when the animal treated her in a similar manner. Being struck with the concern evinced by the creature she quietly followed it upstairs into a bedroom whither it led her; there it commenced barking, looking under the bed and then up in her face. Upon examination a cat was discovered there quietly demolishing a beef-steak, which it had feloniously obtained. The most curious feature is that the cat had been introduced into the house only a short time before, and that bitter enmity prevailed between her and her canine companion."*

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* Zoologist, p. 2131.

This is a capital case. "Instinct" might undeniably have led the terrier to attack the cat and attempt to deprive her of her booty. But we find this natural impulse here completely restrained for the attainment of a definite end. The terrier must have drawn the conclusion that his enemy, if detected in theft, would probably suffer severe punishment, —perhaps even death—and he therefore laid an information against her, calculating thus to get rid of her without compromising himself. This incident plainly proves that brutes are capable of self-control—that they do not always blindly and necessarily follow their physical appetites, but can, like man, forego a present indulgence for what appears to them a greater good in prospect. It is as clear a case of self-determination,—of appetite and passion governed by the will,—as any which human biography can show.

It will possibly be objected that we give no instance of self-control except in species which have been brought under human influence. The reply is obvious; if a free will or a power of self-determination has been created in such animals by man's intervention, its presence or absence is obviously a matter of small moment and quite inadequate to establish a "great gulf" between man and "brute." But if the will has *not* been thus created, it is probable, or rather certain, that were man better acquainted with the habits of wild animals he would find in their conduct also cases of self-control.

It will further be objected that in the vast majority of cases, animals merely act in accordance with the dictates of their ruling propensities. We grant this, and we ask whether this does not hold good to an almost equal extent with man? Analyse the actions of N'Kygntzgm, the blue-nosed baboon, and you will admittedly find little save the manifestations of ruling propensity. Sift in like manner the conduct of John Nokes, collier, of Hanley, and you will come to the same result. Surely, then, we can regard it as proven that in the matter of self-determination, in the supremacy of will over propensity, there is no difference of kind between man and brute.

Were animals really what vulgar human opinion supposes —did they simply and in all cases follow their propensities in the machine-like manner so commonly attributed to them, it is difficult to see how any individuality of character could exist. All the members of one species would have the same mental abilities and the same dispositions. But this is precisely what is not the case. Among a dozen animals of the same species and even of the same breed differences of character are found as decided as occur among a similar number of men. Any breeder or trainer of horses, cattle, dogs, or poultry, would greet with laughter,—loud, if not Olympian,—the theorist who should assert that these animals display anything like identity of disposition. There are the obstinate and the docile, the timid and bold, the open and the treacherous, the placable and the revengeful. In fact, to find two horses or two dogs precisely alike in every point of character that man can distinguish would be as difficult as to find two human beings similarly identical. How much greater, then, would be the range of character visible if we could see them with the eyes of their own species!

Perhaps the usual evasion may be attempted that such various development of temper and disposition is to be found among tame animals alone. The objection is baseless. Capture a number of wild elephants, hawks, ravens, parrots, and try to tame them. You will find still the same variety as you would among animals born in a state of tameness. The differences are found by man, not created.

We will next endeavour to show—what indeed, follows as a corollary from the foregoing considerations—that animals are capable of vice, hoping that this circumstance may lead man to recognise them as brothers.

To eat more than hunger demands merely for the sake of the sensuous enjoyment thus obtainable, has been always, in man, branded as a serious vice, and has indeed been classed among the "seven deadly sins" of mediæval tradition.* This transgression has been found to impair human health, and to blunt mental action. How is it in this respect with brutes? Do they never eat more than they can digest and assimilate? Do they never suffer consequently in their health? Most assuredly. Cows have been known to gorge themselves with clover till they have died from repletion. Ducks often suffer from their own greediness. Similar cases of gluttony are, of course, more rare among wild animals, who neither find food in such abundance nor are so undisturbed in its enjoyment. Yet even they, in homely phrase, at times eat more than does them good. Here, then, we see that brutes have a certain liberty of action. They can be either temperate or gluttonous. In the former case they preserve their health; in the latter case they bring upon themselves disease or perhaps death. If the gluttonous animal gives unchecked play to its propensities, does not the temperate animal, like the temperate man resist temptation and exercise a certain amount of self-restraint? Is it not, for so doing, equally entitled to credit?

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* It is a remarkable fact that the discharge of any voluntary physical function to which *no* pleasure is attached was never pronounced a vice, even if exercised in excess. But those whose importance the Creator has indicated by rendering them pleasant were branded as sinful not merely when discharged in excess, but even when kept within the bounds of moderation,—and this in the exact ratio of their pleasurableness.

The Rev. G. Henslow, in his able and interesting work on the "Theory of Evolution of Living Things," makes some remarks which must here be taken into consideration if only for their cool *naïveté* of assumption. Says this author:—"In obeying those laws of self-preservation and propagation which have been impressed upon it, it is extremely probable that wild animals eat and drink not for the purpose of eating and drinking, but to maintain bodily life only. The laws of propagation are obeyed, but union is probably not resorted to for mere union's sake. Animals show no signs of distinguishing the object from the means. Man alone can see that eating is pleasant, and so often eats for the mere sake of eating, and similarly of other pleasures."

If animals eat only to maintain life it is somewhat strange that they are so extremely nice in the quality of their food. Birds and wasps, in their visits to our gardens, select fruit with a care surpassing that of any human epicure. They attack only the finest pears, peaches, &c., and of these they eat only the sunny side. Mr. Henslow confounds the *result* of an action with the *motive*. Man, at least in his adult state, and possibly the higher animals, know that the result of eating is the prolongation of life, and that abstinence would be ultimately fatal. But neither man nor animal, as a rule, eats from any other motive than to avoid the pains of hunger and to secure the pleasures of eating. We will even venture to say that the less ultimate results are held in view in the gratification of any physical appetite the more perfectly those very results are obtained. As regards the "laws of propagation." We can bring forward facts proving that among animals union *is* resorted to for mere union's sake. Into what absurdities men are led by their notions of what is "extremely probable!"

It may be urged that the moderation of an animal may spring, not from its greater power of self-control, but from its feebler appetites. We cannot deny that this is a possible explanation. But it may, with equal right, be extended to man also. Who knows that the temptation which the saint resists is really as strong as that to which the sinner succumbs? Are we not, in cases of reformation of character, frequently left in painful doubt whether the "convertite" is forsaking his vices or his vices forsaking him?

Alcoholic excitement is not one of the prevailing vices of brutes, from the satisfactory reason that they are under the operation of a natural Maine Law.* Two cases of drunkenness, in a cow and a sow respectively, are on record. Both these occurred in Scotland. It is only fair to surmise that the offending animals, like some of their two-legged compatriots thought fit, in the words of Hudibras, to :—

> "Compound for sins they were inclined to,
> By damning those they had no mind to."

A later instance of undeniably "beastly" drunkenness is given in the "Greenock Advertiser." Two rats got "that fou" in the shop of a spirit merchant in the town by dint of consuming the dribblings from a barrel of strong ale, and were killed before they could stagger off to their holes.

It is generally known that most of the Quadrumana, when thrown among human society, learn very readily to like a glass of strong liquor,—a fact which should go far to establish their title to a place on the right side of the "gulf." It is no less certain that some of the less reputable monkeys are captured by leaving near their haunts vessels filled with a kind of beer. They come, drink and become drunken, and in that state commit the very venial error of mistaking the negro, who comes to lead them into captivity, for one of their own species.

From alcoholism we are naturally led to the love of the narcotics, as tobacco, opium, Indian hemp, coca, and the like. That man has a widely-spread craving for these so-called "keys of paradise," has been sufficiently shown. But apes, also, in captivity have been known to indulge in the "weed" with evident relish. Imitation, say you? Probably enough; but has imitation no part in the spread of these minor vices among mankind? Nine smokers out of ten first take to the pipe or the cigar from the tendency—common alike to man and brute—of doing what others do. A love for tobacco in the solid form, also, is not peculiar to man. At a tavern in Bradford there flourished some years ago a goat, whose exploits in tobacco-chewing were not unknown to fame throughout the "land of woollen." A frequenter of the house occasionally won money from strangers, by betting that "himself and another" would eat a pound of tobacco in ten minutes. If the wager was accepted he would order in a pound of ordinary shag tobacco, put a modest pinch in his own mouth and call in the goat, who soon disposed of the remainder. It is not on record that Billy suffered in his health or displayed any marks of penitence after these performances.

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* This is not literally true. Alcohol, in small doses, is being detected in natural productions, in which man has had no part.

Turn we next to dishonesty in the widest sense of the word,—the vice most in favour in this virtuous age. The lower animals labour under the disadvantage of having no stock-exchange and of not using bills of exchange. But they indulge to the best of their means and opportunities in deceit, affectation, and hypocrisy.

The Rev. J. G. Wood, in his recent interesting work "Man and Beast," gives an instance of a terrier who, finding that a companion had anticipated him in getting possession of a snug seat, suddenly pricked up his ears, dashed into a corner of the room, and begun scratching and barking furiously. The other dog, believing that this commotion indicated the presence of a rat, hastened to the spot, when the terrier at once ran back and secured the coveted cushion. Mr. Wood—we quote from memory—very justly brings forward this incident as a proof of intelligence in dogs. But it is equally a proof of dishonesty. It is a clear case of obtaining something desirable on false pretences.

Hypocrisy is almost as prominent among the Felidæ as among men. If a delicate morsel is thrown to a cat, she will, except very hungry, assume an air of utter unconcern. But all the while she knows its position to a hair's breadth, and when no one appears to be looking, it will be at once seized and swallowed. Or if a bowl of cream is standing in an accessible position, pussy appears lost in the brownest of studies. Her eyes are closed, or if open are directed anywhere save towards the tempting object; yet all the time she is watching her opportunity. Whether in cats or in man this failing is invariably the "homage which vice pays to virtue" we leave an open question.

The following instance of deceit and hypocrisy in a terrier is given by Mr. G. J. Romanes in "Nature" (May 27th, 1875, p. 66).

"He used to be very fond of catching flies upon the window panes, and if ridiculed when unsuccessful was very much annoyed. On one occasion, in order to see what he would do, I purposely laughed immoderately every time he failed. It so happened that he did so several times in succession—partly, I believe, in consequence of my laughing—and eventually he became so distressed that he positively *pretended* to catch the fly, going through all the appropriate actions with his lips and tongue, and afterwards rubbing the ground with his neck, as if to kill the victim: he then looked up at me with a triumphant air of success. So well was the whole process simulated that I should have been quite deceived had I not seen that the fly was still upon the window. Accordingly I drew his attention to this fact, as well as to the absence of anything upon the floor, and when he saw that his hypocrisy had been detected, he slunk away under some furniture, evidently much ashamed of himself."

This last point is most significant, fully overturning the vulgar notion of the absence of moral life in brutes, and of their total want of conscience.

That animals steal is a familiar expression. But we must here distinguish two different cases. We speak of hares stealing our corn, and of blackbirds plundering our cherries; but in neither case have we any reason to conclude that the offenders can distinguish between the crops in cultivated lands, and the spontaneous produce of woods and wastes. But not a few species both of birds, quadrupeds, and insects evidently recognise the idea of property. This is proved by the fact that they display far greater courage and pertinacity in defence of their nests, their haunts, and their accumulations, than under other circumstances. A dog, that when trespassing is put to flight by a gesture or a shout, becomes a formidable opponent in his own yard. If, then, such animals know what property is, and yet at times make free with it, we may justly pronounce them conscious thieves. Rooks are apt to purloin sticks from each other's nests; but if the offender is detected and cuffed by the rightful owner, conscience makes a coward of him. and he merely defends himself by flight. More than this—rooks have some rudiments of criminal law. Inveterate thieves are sometimes banished from the rookery, severely beaten, or even killed outright.* But law pre-supposes the notions of right and wrong, and could never, therefore, have arisen among beings incapable of making this distinction.

As another vice, we may take quarrelsomeness—a term which we need surely not define. This attribute is highly conspicuous in the human species, nowhere perhaps more strikingly than in that part of the English nation who inhabit the borders of Yorkshire and Lancashire. But certain dogs show the very same disposition, and without the smallest provocation take every opportunity of attacking horses, cows, sheep, and human beings. There is a well-authenticated instance of a terrier who, in picking a quarrel contrived, as skilfully as if trained in the Kanzlei of Prince Bismarck to place himself technically in the right. He would time his movements so that some passenger should stumble over him, and would then fasten on the calf of his leg. With a most statesmanlike aptitude he selected the aged, the infirm, and the ill-dressed, as the objects of his cunningly-planned attacks. Lord Lytton tells us that the dog is a gentlemanly animal!

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* A most interesting account of the habits of rooks was given by Mr. Ashley, of Sheffield, in a lecture delivered before the Mechanics' Institute of that town about twenty years ago.

Closely connected with quarrelsomeness is the most fiendish of all man's failings—overlooked, as it is, by world-betterers and vice-suppressers—his disposition to give pain, bodily or mental, for mere amusement. There are few human beings, of the male sex at least, who do not delight in tormenting other creatures, whether of their own or of some different species.* Yet even this kind of malignity is not unshared by man's poor relations. Fall among wolves, and they will kill you for the straightforward purpose of eating you. Fall among blue-nosed baboons and they will torment you to death "just for the fun of the thing." Could a Red Indian, or even a normal English school-boy, greatly improve upon this?

With the exception of a few genuine—not professional—philanthropists, man is remarkable for persecuting such of his own species as are unfortunate. This diabolical propensity shows itself in a variety of forms. "Hit him again, he has no friends," is scarcely a parody on the avowed opinions of the less hypocritical of the species. Those who lay claim to higher culture express their sorrow for the calamities of a neighbour by eschewing his society, or perhaps even by asking him whether he does not recognise in his sufferings a well-merited Divine chastisement?

Odious as is this trait of human character, man has no monopoly thereof. The wounded wolf is at once devoured by his comrades.

Cattle, both wild and tame, have been observed to gore and trample to death a sick or lame member of the herd. A rook, accidentally entangled in the twigs of a tree, is pecked and buffetted by its fellow-citizens. This, of course, has been pronounced "instinctive." Animals, we are gravely told, put an end to sufferings which they are powerless to alleviate. They do not wish that the herd should be encumbered with a sickly or wounded member. Taking these explanations for what they are worth, we still ask whether man's ill-treatment of his unfortunate fellows is not the ultimate transformation of the very same instinct.

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* When an Englishman talks about amusement, it may be inferred as a general rule that he means killing something.

But, further, the alleged instinct is not common to all gregarious animals. Monkeys and baboons cherish and defend the young, the helpless, and the wounded of their own species. Ants will take great pains to rescue a member of their community who is in distress.

Looking in a different direction, we must acknowledge that among viviparous animals and birds, the females are, as a general rule, no less careful of their young than are human mothers. In thus acting they are undoubtedly obeying one of the "laws" of their nature. But they can also transgress such law, just as we occasionally find a woman who will neglect, ill-treat, or even kill her child. So is it with female brutes. Sometimes, though rarely, they will abandon or destroy their young. This is a fact well known to the breeders of tame animals. The seller of a mare, a cow, or a sow, is often asked by an intending purchaser, "Is she a good mother?" It must be remarked that neglect of family is by no means the invariable result of want of food, or of danger and annoyance. Birds will, as is well known, sometimes forsake their nests from fear. But a hen has been known to leave her chickens to the mercy of accidents without any conceivable motive save caprice, or the want of ordinary natural affection. Cats, though ordinarily very affectionate mothers, and sows, sometimes devour their young. Here, therefore, we find, again, that the lower animals are not bound down by absolute necessity to one unvarying line of conduct. Like man, they have the power to deviate from what is for them natural, normal, or right. Occasionally they make use of such power. What may be the causes of, or the motives for, such transgression, is not here the question. Enough for us that it exists.

We now come to a part of the subject which, though essential to our argument, we cannot enter into at any length. Do brutes invariably obey the "law of their being" as regards the mutual relations of the sexes? Far from it. The nearer brutes approach to man, the more they are inclined to sin against what, in modern cantology, is exclusively styled "morality." With animals which pair conjugal fidelity is, indeed, more general than with mankind. A petty negro chief laughed at the notion of keeping to one wife, "like the monkeys." Still it is far from being universal, and nowhere are exceptions more frequently found than among pigeons, which with a rare depth of wicked satire, have been selected as types of matrimonial faith.

The existence of hybrids shows a departure from what nature should enjoin. Such beings have been produced respectively, not alone between the horse and the ass, but between the horse and the quagga, the horse and the zebra, the ass and the zebra, the lion and the tiger, the hare and the rabbit (leporides), and between a great variety of birds of the poultry, pheasant, grouse, duck, and finch groups. To the dismay and indignation of certain theorists some of these hybrids are capable of reproduction.

It has been objected that these instances occur only through human intervention. This is by no means the fact. Hybrids between distinct species of grouse have been met with in a wild state.

Instances of hybridism are likewise said to have occurred between animals much more widely remote in their respective natures. Such cases are doubtful, and are certainly not essential to our argument. But intercourse not unfrequently takes place between animals of different species where no offspring has been positively proved to result.

Many more instances of brute frailty might be given were it needful or desirable.

It has been asserted that "mere brutes" never commit suicide. This is a wanton, it might be said an impudent, assumption. If a negro, sold into slavery, refuses food and starves himself to death, as sometimes happened in the palmy days of the "black ivory-trade," men say that he has committed suicide rather than live in bondage; but if an animal, bird, or reptile, taken away from its native haunts and shut up in a cage, persistently refuses food and dies in consequence, why should not the same name be applied to conduct precisely similar? Yet cases of this kind, in which the love of liberty and independence asserts itself in flat defiance of the strongest of all instincts are by no means rare. There is great difficulty in inducing some animals to eat in captivity, even if supplied with the very kind of food which they select when at large. As an example, we may mention the common viper, which generally starves itself to death in captivity, regardless of the offer of the choicest mice. But there are many instances among domestic animals, proving that life-weariness and the determination to end miseries in a sudden manner are not confined to the human race.

"*Suicide by a Dog.*—A day or two since a fine dog, belonging to Mr. George Hone, of Frindsbury, near Rochester, committed a deliberate act of suicide by drowning in the Medway, at Upnor, Chatham. The dog had been suspected of having given indications of approaching hydrophobia, and was accordingly shunned and kept as much as possible from the house. This treatment appeared to cause him much annoyance, and for some days he was observed to be moody and morose. On Thursday morning he proceeded to an intimate acquaintance of his master's at Upnor, on reaching the residence of whom, he set up a piteous cry on finding that he could not obtain admittance. After waiting at the house some little time, he was seen to go towards the river close by, when he deliberately walked down the bank, and after turning round and giving a kind of farewell howl, walked into the stream, where he kept his head under water, and in a minute or two rolled over dead. This extraordinary act of suicide was witnessed by several persons. The manner of the death proved pretty clearly that the animal was not suffering from hydrophobia."—*Daily News*.

"*Suicide of a Horse*.—A correspondent writes :—'A few nights ago a poor creature, worn to skin and bone, put an end to his existence in a very extraordinary manner. His pedigree is unknown, as he was quite a stranger. A very worthy gentleman here met him in a public market, and thinking he could find employment for him, put him to work, but it was soon discovered that work was not his forte; in fact, he would do anything save work and go errands. His great delight was to roam about the fields and do mischief. People passing him used to ejaculate, "Ugh, you ugly brute," when they saw the scowl which was continually on his face. His master tried to win him by kindness. The kindness was lost upon him. He next tried the whip, then the cudgel, but all in vain. Work he would not. And as a last resort the punishment of Nebuchadnezzar of old was tried. He was turned out, "but house or hauld," to eat grass with the oxen. With hungry belly and broken heart he wended his lonely way down by the Moor's Shore, passed Luckyscaup, turned the Moor's Point, and still held on his lonely way, regardless of the wondering gaze of the Pool fishermen. At length he arrived at a point opposite the wreck of the *Dalhousie*, where he stood still; and while the curiosity of the fishermen was wound to the highest pitch as to what was to follow, he, neighing loudly and tossing his old tail, rushed madly into the briny deep, got beyond his depth, held his head under the water, and soon ceased to be. The fishermen conveyed the true, although strange and startling tidings, to the respected owner, that his horse had committed suicide.' "—*Dundee Advertiser*.

There are several other authenticated cases on record where dogs have committed suicide by drowning. It is important, as showing intention, that dogs are perfectly aware of the results of prolonged immersion in water, as evinced by their so frequently rescuing children when in danger of drowning. Were dead brutes honoured with a searching investigation, we might perhaps find such instances far more frequent than we suspect. They have, however, scantier facilities for self-murder than man, and possibly slighter temptations, as being doubtless, upon the whole, less miserable.

The various actions above mentioned are all departures from the normal or natural conduct of the species concerned, and of course lead us again to the conclusion that brutes *can* do wrong, and if wrong, that they are consequently able also to do right.

Perhaps it may be argued by the captious that though gluttony, neglect of offspring, suicide, and the like, are wrong in themselves, and are hurtful to the offending animal and its species, yet that brutes have no conscience, and neither feel any satisfaction in "obeying the laws" of their nature nor any remorse upon transgression. To this we may in the first place reply with a *tu quoque*—a retort for once satisfactory, as it withdraws the pretended distinction. Man does not appear to have any inborn and infallible knowledge of right and wrong. His vaunted conscience, when it is more than a mere figure of speech, is a creature of conventions and traditions. There is no vice, no crime even, how horrible soever, which at some time or in some part of the world man has not practised without a shadow of self-reproach. He has suffered, indeed, from his errors, but no more than the brutes does he, generally speaking, trace his sufferings to their true causes. Sir J. Lubbock states in his "Origin of Civilization" that after inspecting nearly all existing records of savage life, he was unable to find any case of a savage having evinced remorse after the commission of any crime.

But, on the other hand, does man really *know* that brutes are void of all trace of conscience—that they feel no joy when they have acted aright, and no sorrow when they have done amiss? He has no proof—merely wanton assumption. Facts prove that certain animals do feel shame, sorrow, or remorse, when they have departed from what to them is the standard of right; and what more can reasonably or fairly be demanded?

We have thus, we submit, established that the lower animals have a moral life, that they can do right or do wrong, and that like man they avail themselves of their power to do the latter. Surely henceforth a fellow feeling ought to make him wondrous kind to them all. Community in vice, or even in peccadillos, has always been a wonderful leveller of distinctions.

II. THE LONGEVITY OF BRAIN-WORKERS.*

By GEORGE M. BEARD, A.M., M.D., New York.

THOMAS Hughes, in his life of "Alfred the Great," makes a statement that "the world's hardest workers and noblest benefactors have rarely been long-lived." That any intelligent writer of the present day, and especially a writer who, like Mr. Hughes, is a thoughtful student of mental hygiene, should make a statement so absolutely untrue, shows how hard it is to kill an old superstition.

The remark is based on the mischievous theory, which—against the clearest evidence of general observation—has been held for centuries, that the mind can be used only at the injurious expense of the body. This theory has been something more than a mere popular prejudice; it has been a professional dogma, and has inspired nearly all the writers on hygiene since medicine has been a science. On the basis of this theory, intellectual and promising youth have been dissuaded from entering brain-working professions; and thus, much of the choicest genius has been lost to the world; students in college have abandoned plans of life to which their tastes inclined, and gone to the farm or workshop; authors, scientists, and investigators in the several professions have thrown away the accumulated experience of the best half of life, and retired to pursuits as uncongenial as they were profitless. The superstition, for it hardly deserves to be called a theory, has therefore wrought immense evil specifically by depriving the world of the services of some of its best endowed natures, and generally by fostering a habit of accepting statement for demonstration.

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* Communicated by the Author. Read before The American Public Health Association, 1874.

Between 1864 and 1866, while preparing a thesis for graduation, I obtained statistics on the general subject of the relation of occupation to health and longevity that convinced me of the error of the accepted teachings in regard to the effect of mental labour. These statistics, which were derived from the registration reports of this country and of England, and from a study of the lives of many prominent brain-workers, were incorporated in an essay on the subject that was delivered before an Association of Army and Navy Surgeons in New Orleans in 1863, and afterwards published in the "Hours at Home" Magazine. The views I then advocated, and which I enforced by statistical evidence, were:—

1st. That the brain-working classes—clergymen, lawyers, physicians, merchants, scientists, and men of letters,—lived very much longer than the muscle-working classes.

2nd. That those who followed occupations that called both muscle and brain into exercise, were longer lived than those who lived in occupations that were purely manual.

3rd. That the greatest and hardest brain-workers of history have lived longer on the average than brain-workers of ordinary ability and industry.

4th. That clergymen were longer lived than any other great class of brain-workers.

5th. That longevity increased very greatly with the advance of civilisation; and that this increase was too marked to be explained merely by improved sanitary knowledge.

6th. That although nervous diseases increased with the increase of culture, and although the unequal and excessive excitements and anxieties attendant on mental occupations of a high civilisation were so far both prejudicial to health and longevity, yet these incidental evils were more than counterbalanced by the fact that fatal inflammatory diseases have diminished in frequency and violence in proportion as nervous diseases have increased; and also that brain-work is, *per se,* healthful and conducive to longevity.

Many of these views have since received various and powerful confirmation, and by a number of independent observers.* The statistics on this subject I have endeavoured to use without abusing them; to draw from them only those lessons that they are really capable of teaching. Among those classes who live mainly by routine and muscular toil (mechanics, artisans, labourers, &c.) change of occupation is the rule rather than the exception, especially in this country; and any statistics of mortality derived from the Registration Reports, are, so far as these classes are concerned, of but little value in the study of the relative effects of the different occupations on health and longevity. Another important complication arises from the fact that certain occupations, as clerkships, positions in factories, teaching, &c., are followed almost exclusively by the young and middle-aged; while other callings, as judgeships, are filled only by those in middle and advanced life. Another difficulty arises from the fact that some important occupations, as journalism, for example, are adopted only by a limited number; and the number in them who annually die is too small to afford any basis for comparison. But this generalisation is, I am persuaded, admissible, that the greater majority of those who die in any one of the three great professions—law, theology, and medicine—have, all their lives, from twenty-one upwards, followed that profession in which they died. The converse generalisation, that the great majority of those who die in the muscle-working avocations have all their lives followed some kind of muscle-working employment, however frequently they may have changed from one to another at different periods, is also true. Very few who once fairly enter theology, medicine, or law ever permanently change to a purely physical calling; and, on the other hand, the number of those who begin life as farmers, labourers, and mechanics, and end it as lawyers, physicians, or clergymen, is quite limited, even in the United States, where every man has a better chance to follow the bent of his genius than in any other country.

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* Those who desire to obtain the detailed facts on this subject are referred to my Essay in "Hours at Home" (Oct., 1867); to my series of papers on "Hygiene for Students," in the "College Courant" (1869); to my "Home Physician," p. 380; to Dr. Derby's "Registration Reports of Massachusetts" and Farr's "Registration Reports of England" (Supplement to 22nd); to Dr. Edward Jarvis's Papers on the "Increase of Human Life," in "Atlantic Monthly" (Oct., Nov., and Dec., 1869); to Dr. Elam's "Physician's Problems;" Hon. B. G. Northrup's "Report of the Connecticut Board of Education" (1869, pp. 61-74); and to the "Reports of the Life Insurance Company for Clergymen" (Bible House, N. Y.).

A comparison, therefore, of the longevity of the professional and of the muscle-working classes, as derived from Registration Reports, such as I have made, is quite justifiable. The value of this comparison would be vitiated if it could be proved that those who enter the professions are originally healthier and stronger, and come from better stock, than those who enter physical avocations; but in this country the practice has been to allow the more delicate members of a family to enter a profession, whilst the tough and hardy work on the farm or learn a trade. Here, as in Europe, there is growing up a distinctively intellectual class who live solely by brain-work; it is, however, not from this class alone, but from the farming, mercantile, and artisan class, that the ranks of the professions are filled.

Great Longevity of Great Men.—I have ascertained the longevity of five hundred of the greatest men in history. The list I prepared includes a large proportion of the most eminent names in all the departments of thought and activity.

It would be difficult to find more than two or three hundred illustrious poets, philosophers, authors, scientists, lawyers, statesmen, generals, physicians, inventors, musicians,, actors, orators, or philanthropists, of world-wide and immortal fame, and whose lives are known in sufficient detail, that are not represented in the list. My list was prepared, not for the average longevity, but in order to determine at what time of life men do their best work. It was, therefore, prepared with absolute impartiality; and includes, of course, those who, like Byron, Raphael, Pascal, Mozart, Keats, &c., died comparatively young. Now the average age of those I have mentioned I found to be 64·20.

The average age at death at the present time of all classes of those who live over twenty years is *about fifty*. Therefore, the greatest men of the world have lived longer, on the average, than men of ordinary ability in the different occupations by fourteen years; six years longer than physicians and lawyers; nineteen or twenty years longer than mechanics and day labourers; from two to three years longer than farmers; and a fraction of a year longer than clergymen, who are the longest-lived class in our modern society. The value of this comparison is enforced by the consideration that longevity has increased with the progress of civilisation, while the list I prepared represents every age of recorded history. A few years since I arranged a select list of one hundred names, comprising the most eminent personages, and found that the average longevity was *over seventy years*. Such an investigation any one can pursue; and I am sure that any chronology, comprising from one to five hundred of the most eminent personages in history, at any cycle, will furnish an average longevity of from sixty-four to seventy years. Madden, in his very interesting work, "The Infirmities of Genius," gives a list of two hundred and forty illustrious names, with their ages at death. The average I found to be sixty-six and a fraction.

In view of these facts, it may be regarded as established that "the world's hardest workers and noblest benefactors" have usually been very long lived.

Causes of the Great Longevity of Brain-Workers.

The full explanation of the superior longevity of the brain-working classes would require a treatise on the science of sociology, and particularly of the relation of civilisation to health. The leading factors, accounting for the long life of those who live by brain-labour, are as follows:—

1. *The inherent and essential healthfulness of brain-work.* To work is to grow; and growth, except it be forced, is always healthful. It is as much the function of the brain to cerebrate as of the stomach to digest; and cerebration, like digestion, is normal, physiological, and healthful. In all organisations of force the exercise of force develops more force; work evolves strength for work. A plant that is suffered to bud and bloom is more sturdy and longer lived than the plant that is kept from the light or trimmed of all its blossoms, By thinking, we gain the power to think; functional activity, within limits, tends to vigour and the self-preservation of an organ and of the body to which the organ belongs. The world has been taught that the brain can be developed only at the expense of the other organs of the body; granting that brain-work strengthens the brain itself, the rest of the body is impoverished thereby—hence disease, and early death. But recent investigations in cerebro-physiology seem to indicate that the centres of thought in the anterior region of the brain are also the centres of muscular motion; and hence it may perhaps be inferred that to develop the brain may be one method of developing the muscles.* It is certain that the brain-working classes are, on the average, well developed muscularly; and in size and weight are superior to the purely muscle-working classes.

2. *Brain-workers have less worry, and more comfort and happiness, than muscle-workers.* Worry is the converse of work; the one develops force, and the other checks its development, and wastes what already exists. Work is growth; worry is interference with growth. Worry is to work what the chafing of a plant against the walls of a

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* I here refer to the experiments of Hitzig, of Berlin, in the electrical irritation of the brains of living animals. These experiments have been confirmed by a variety of experiments undertaken by Ferrier, of London, by myself, and other observers. I use the word centre, in an experimental sense; and the above theory of the relation and definition of the thought centres, and muscle centres, is merely a provisional suggestion. (See "Archives of Electrology and Neurology," May, 1874, for a record of my own experiments, with remarks, and also a general *resumé* of facts).

greenhouse is to limitless expansion in the free air. In the successful brain-worker worry is transferred into work; in the muscle-worker, work too often degrades into worry. Brain-work is the highest of all antidotes to worry; and the brain-working classes are therefore less distressed about many things, less apprehensive of indefinite evil, and less disposed to magnify minute trials, than those who live by the labour of the hands. To the happy brain-worker, life is a long vacation; while the muscle-worker often finds no joy in his daily toil, and very little in the intervals. Scientists, physicians, lawyers, clergymen, orators, statesmen, literati, and merchants, when successful, are happy in their work, without reference to the reward, and continue to work in their special callings long after the necessity has ceased. Where is the hod carrier that finds joy in going up and down a ladder; and, from the foundation of the globe until now, how many have been known to persist in ditch-digging, or sewer-laying, or in any mechanical or manual calling whatsoever, after the attainment of independence? Good fortune gives good health. Nearly all the money of the world is in the hands of brain-workers; to many, in moderate amounts, it is essential to life, and in large or comfortable amount it favours long life. Longevity is the daughter of luxury. Of the many elements that make up happiness, mental organisation, physical health, fancy, friends,* and money—the last is, for the average man, greater than any other, except the first. Loss of money costs more lives than the loss of friends, for it is easier to find a friend than a fortune. Almost all muscle-workers are born, live, and die poor. To live on the slippery path that lies between extreme poverty on one side, and the gulf of starvation on the other; to take continual thought of to-morrow, without any good result of such thought; to feel each anxious hour that the dreary treadmill by which we secure the means of sustenance for a hungry household may, without warning, be closed by any number of forces, over which one has no control; to double and triple all the horrors of want and pain, by anticipation and rumination,—such is the life of the muscle-working classes of modern civilised society; and when we add to this the cankering annoyance that arises from the envying of the fortunate brain-worker who lives in ease before his eyes, we marvel not that he dies young, but rather that he lives at all.*

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* I do not here refer to accumulated wealth exclusively, but to income or sufficient amount to purchase comforts and luxury. Many persons (and notably successful professional men), live out their days in comfort and luxury, although they never succeed in accumulating fortunes; to them, their reputation is wealth and capital.

3. *Brain-workers live under better sanitary conditions than muscle-workers.* They have better food and drink, warmer clothing, breathe purer air, and are less exposed to fatal accident and the poison of disease. None of the occupations are ideal; none fulfil all the laws of health; but the muscle-working callings are all more or less unhealthy; tradesmen, artisans, common labourers, and even farmers (who combine muscle with brain-work), all are forced to violate sanitary law every hour of their lives; not one out of ten have enough good food; many are driven by passion and hunger to excess in the worst forms of alcoholic liquors; for a large number sleep is a luxury of which they never have sufficient for real recuperation; healthful air is but rarely breathed by the labouring classes of any large city; exposure to weather, that brings on fatal inflammatory diseases; accidents that cripple or kill—in all these respects, the muscle-worker, as compared with the brain-worker, is at stupendous disadvantage.

4. *The nervous temperament, which usually predominates in brain-workers, is antagonistic to fatal, acute, inflammatory disease, and favourable to long life.* Comparative statistics have shown, that those in whom the nervous temperament prevails live longer than those in whom any one of the other temperaments prevail, and common observation confirms the statement. Nervous people, if not too feeble, may die every day. They live, but they do not die; they talk of death, and each day expect it, and yet they live. Many of the most annoying nervous diseases, especially of the functional, and some even of the structural varieties, do not rapidly destroy life, and are indeed consistent with great longevity. I have known a number of men and women who were nervous invalids for half a century or more, and died at an advanced age. It is one of the compensations of nervousness that it protects the system against those febrile and inflammatory diseases that are so rapidly fatal to the sanguine and the phlegmatic. The nervous man can expose himself to malaria, to cold and dampness, with less danger of disease, and with less danger of death if he should contract disease, than his tough and hardy brother. This was shown in the late war, when delicate, ensanguined youth, followed by the fears of friends, went forth to camp and battle, and

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* Those who question the truth of the above picture, are referred to any of the recently published essays and treatises on the condition of the peasantry of England. Observations show, that in our own country, not only in large cities, but in all manufacturing towns, and even in farming districts, the labouring classes are as badly circumstanced as I have stated.

not only survived, but grew stout amid exposures that prostrated by thousands the lumbermen of Maine, and the sons of the plough and the anvil. In the conflict with fevers and inflammations, strength is often weakness, and weakness becomes strength—we are saved through debility. Still further, my studies have shown that, of distinctively nervous diseases, those which have the worst pathology and are the most hopeless, such as locomotor ataxia, progressive muscular atrophy, apoplexy with hemiplegia, and so on, are more common and more severe, and more fatal among the comparatively strong and tough than among the most delicate and finely organised.* Cancer, even, goes hardest with the hardy, and is most relievable in the nervous.

5. *Brain-workers can adapt their labour to their moods and hours and periods of greatest capacity for labour better than muscle-workers.* In nearly all intellectual employments there is large liberty; literary and professional men especially are so far masters of their time that they can select the hours and days for their most exacting and important work; and when from any cause indisposed to hard thinking, can rest and recreate, or limit themselves to mechanical details. Thus, there is less of the dreadful in their lives; they work when work is easy, when the desire and the power are in harmony; and, unlike their less fortunate brother in the mill or shop, or diggings, need not waste their force in urging themselves to work. Forced labour, against the grain of one's nature, is always as expensive as it is unsatisfactory; it tells on the health and on life. Even coarser natures have their moods, and the choicest spirits are governed by them; and they who worship their moods do most wisely, and those who are able to do so are the fortunate ones of the earth.

Again, brain-workers do their best work between the ages of twenty-five and forty-five; before that period they are preparing to work; after that period, work, however extensive it may be, becomes largely a matter of routine. Lawyers and physicians do much of their practice after forty; but to practice is easy, to learn is hard—and the learning is done before forty or forty-five. In all directions, the French motto holds true, "It is the first step that costs." Successful merchants lay the foundations of fortune in youth and middle life, to accumulate, and recreate, and take one's ease in old age; thus they make the most when they are doing the least, and only become rich after they have ceased trying to be so.*

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* In my paper on "Spinal Congestion and Locomotor Ataxia," in the "Philadelphia Medical Times" for January 24 and 31, 1874, I have discussed this point in some detail.

With muscle-workers there is but little accumulation, and only a limited increase of reward; and in old age, after their strength has begun to decline, they must, with increasing expense, work even harder than before.

To this should be added the consideration that manual employments cost as much force after they are learned as before; they can never, like many intellectual callings, become so far forth matters of routine as to require little effort. It is as hard to lay a stone wall after one has been laying it fifty years as during the first year. The range of muscular growth and development is narrow, compared with the range of mental growth; the day-labourer soon reaches the maximum of his strength. The literary or scientific worker goes on from strength to strength, until what at twenty-five was impossible, and at thirty difficult, at thirty-five becomes easy, and at forty a pastime; and besides he has the satisfaction that the work done so easily at thirty-five and forty is incomparably better than the work done with so much difficulty at twenty-five.

6. *Comparative longevity of the professions.* Inasmuch as professional men do not usually change their callings, but die in the special profession in which they have lived, the vital statistics, at least of lawyers, physicians, and clergymen, become of value in determining their comparative longevity. I found in my researches, made several years ago, that lawyers and physicians lived to be about fifty-seven or fifty-eight. The difference in the longevity of lawyers and physicians is but trifling. My observations in this respect have been variously confirmed by other statisticians.†

Longevity of the Precocious.

That precocity predicts short life, and is therefore a symptom greatly to be feared by parents, has, I believe, never been questioned. In poetry and in science, the idea has been variously incorporated that early brilliancy is a sure indication of a feeble constitution and an early death. This view is apparently sustained by analogy, and by facts of observation. Plants that are soon to bloom are soon to fade; those which grow slowly live long and decline slowly. Observing these facts, we naturally adhere to the opinion that the same principle should hold good as regards men, but in making the analogy we forget that it loses its force, unless the objects implicated start in life with the same potential force and are surrounded by the same external conditions. It is probable that, of two individuals with precisely similar organisations and under similar circumstances, the one that develops earlier will be the first to die; but we are not born equally endowed and similarly circumstanced. Not only are men unlike in organisation, but they are very widely unlike; between the brain of Shakspeare and the brain of an idiot is a measureless gulf, and we may believe that difference of degrees may be found between the greatest and simply great men. We may believe that some are born with far more potential nervous force than others. They are millionaires in intellect as well as in money, who can afford to expend enormous means without becoming impoverished. An outlay of one hundred dollars may ruin the mechanic working for his daily wages, while the royal merchant may spend a thousand, and barely know it. There are those who can begin their life-work earlier, toil harder and longer, than the average, and yet attain a very great age. The average age of 500 illustrious men, including those who did not exhibit any special precocity, was about 64·20. Of these 500 individuals, among whom there were 25 women, 150 were decidedly precocious, and their average age was 66·50, or more than two years higher than that of the list of 500, that included the precocious and non-precocious. So far as I could ascertain, the instances of extraordinary longevity were as great among the precocious as among those who were not.* My investigations in this department fully confirm the remark of Wieland, that "an almost irresistible impulse to the art in which they are destined to excel manifests itself in future virtuosi—in poets, painters, &c., from their earliest youth."

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* The whole subject of "The Relation of Age to Work," I have discussed in my pamphlet on "Legal Responsibility in Old Age," to which I may refer those who are interested in the subject. What is there written is preliminary to an exhaustive treatise now in the course of preparation.

† "An investigation made by a Berlin physician into the facts and data relating to human longevity shows the average age of clergymen to be 65; of merchants, 62; clerks and farmers, 61; military men, 59; lawyers, 58; artists, 57; and medical men, 56. Statistics are given showing that medical men in England stand high in the scale of longevity. Thus, the united ages of 28 physicians who died there last year, amount to 2354 years, giving an average of more than 84 years to each. The youngest of the number was 80; the oldest, 93; two others were 92 and 89 respectively; three were 87; and four were 86 each; and there were also more than 50 who averaged from 74 to 75 years."

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* A contributor to the "Galaxy" for August (G. W. Winterburn) thus discourses concerning musical prodigies. Investigating the records of the past two centuries, he finds 213 recorded cases of acknowledged prodigies. None of them died before their 15th year, some attained the age of 103—and the average duration of life was 58—showing that with all their abnormal precocity, they exceeded the ordinary longevity by about 6 per cent. Those who died before the age of 21 were, without exception, musicians of the very highest order.

Not only in poetry and painting, but also in philosophy, in science, and in invention—indeed, in every great department in which human nature has displayed itself—it is true, as Milton beautifully remarks, "Childhood shows the man, as morning shows the day."

Madder, in his "Infirmities of Genius," says that "Johnson is indeed of the opinion that the early years of distinguished men, when minutely traced, furnish evidence of the same vigour or originality of mind by which they are celebrated in after-life."

The more closely I study biography, the more strongly I become convinced that the number of really illustrious geniuses who did not give early manifestations of their genius is very limited. I do not forget that some of the currently-reported exceptions are very striking. Thus we are told that Chalmers at school was stupid and mischievous; that Adam Clarke, as a boy, could do nothing but roll huge stones about; that of Sir Walter Scott, his teacher, Professor Dalzell, frankly said—"Dunce he was and dunce he would remain;" that Burns, though a good athlete, showed, in his boyhood, no unusual gifts; that Goldsmith was "a plant that flowered late;" that John Howard, and Napoleon, and Wellington were, to say the least, but little remarkable at school; and that the father of Isaac Barrow is reported to have said that "if it pleased God to take away any of his sons, he prayed that it might be his son Isaac, as being the least promising of them all."

These exceptions, apparent and real, may be explained in two ways:—

1st. The stupidity attributed to men of genius may be really the stupidity of their parents, guardians, and biographers.

Men are precocious, if they are precocious at all, in the line of their genius. It is observed, as Wieland has stated, that almost all artists and musicians are recorded as precocious, the exceptions being very rare. Music and drawing appeal to the senses, attract attention, and are therefore appreciated, or at least observed by the most stupid parents, and noted even in the most superficial biographies. Philosophic and scientific thought, on the contrary, does not at once, perhaps may never, reveal itself to the senses—it is locked up in the cerebral cells. In the brain of that dull, pale youth, who is kicked for his stupidity and laughed at for his absent-mindedness, grand thoughts may be silently growing; the plant which to-day looks stunted and dwarfed may hereafter quicken into life, rise into strength and beauty —to give fruit and shade to many generations. Scott, for example, though he stood low in his class at school, yet very early exhibited genius as an inventor and narrator of "tales of knight-erranty, and battle, and enchantments."

Newton, according to his own account, was very inattentive to his studies and low in his class, but a great adept at kite flying, with paper lanterns attached to them, to terrify the country people, of a dark night, with the appearance of comets; and when sent to market with the produce of his mother's farm, was apt to neglect his business, and to ruminate at an inn over the laws of Kepler.

It is fair to infer that the stupidity attributed to many other distinguished geniuses may be similarly explained. This belief is enforced by the consideration that many, perhaps the majority, of the greatest thinkers of the world seemed dull, inane, and stupid to their neighbours, not only in childhood, but through their whole lives. The brains as well as the muscles of men differ in the times of their growth. Of a dozen individuals of the same endowments and external conditions some will ripen early, others late. This is observed in colleges, where some who take the lead in everything make no further progress in after life. They "strike 12 the first time." Others who, between 15 and 25, are dullards, between 25 and 40 develop great powers.

It is probable, however, that nearly all cases of apparent stupidity, in young geniuses, are to be explained by the want of circumstances favourable to the display of their peculiar powers, or to a lack of appreciation or discernment on the part of their friends. It is very difficult to find any college graduate of remarkable ability who did not, during his collegiate course, in some way manifest the germs of that ability, but there are many who fail in the prescribed routine of studies in the race for literary honours, who yet, in some department or other, do attain distinction. As compared with the world, the most liberal curriculum is narrow; to one avenue of distinction that college opens the world opens ten. In order to learn the material of which a college class is made, it is necessary not only to look at the marks on the tutor's book and scan the prize list of the societies, but also to go out on the ball ground and down the river—we must mingle in the evening carousal and study the social life of the students in their rooms, or their walks, and in vacation.

Whether we regard those general considerations or not, the statistical fact remains that, in spite of the incomplete-ness of biographies, and the ignorance of parents and teachers, *a very considerable proportion of the greatest geniuses of the world are known to have been as remarkable in their precocity as in their genius; and in spite of this precocity were exceedingly long-lived.*

Great precocity, like great genius, is rare. Although I have known but few children whom fond parents did not at some time believe to be more or less superior to the average, yet I do not remember that I ever saw a very precocious child. There is in some children a petty and morbid *smartness* that is sometimes mistaken for precocity, but which in truth does not deserve that distinction.

The manifestation of genius in childhood is as normal and as healthful as its manifestation in maturity; but in childhood, as in extreme old age, the effects of overtaxing the powers are more severely felt than in maturity. Petty smartness is oftentimes a morbid symptom; it comes from a diseased brain, or from a brain in which a grave predisposition to disease exists. Such children may die young, whether they do or do not early exhibit unusual quickness.

The morbidly precocious soon wear themselves out, early find their level, and in after life are stupid or ordinary; the normally physiologically precocious go on from strength to strength, and do not reach their maximum until between thirty and forty; and live longer and are capable of working harder than those of average gifts. There have been noted and oft-quoted instances where the precocious geniuses have died in early manhood, or just at reaching the maximum of their strength, between thirty and forty. The names of Pascal, Mozart, Keats, will be at once recalled. But we forget the infinite number who have died at the same age or earlier, and of the same diseases; but who neither in childhood nor in manhood exhibited any superior genius. The only method of arriving at the truth on the question is the one I have adopted; that is, to obtain the average longevity of a large number, who were known to have been greatly precocious, and compare it with the average longevity of other able men in the same departments.

Those who have not given special thought to this theme will be suprised to learn how early and how strikingly the genius of some of the greatest and longest-lived heroes was displayed. Leibnitz, at twelve, understood Latin authors well, and wrote a remarkable production. Gassendi, "the little doctor," preached at four, and at ten wrote an important discourse. Goethe, before ten, wrote in several languages. Meyerbeer, at five, played remarkably well on the piano. Niebuhr, at seven, was a prodigy; and at twelve had mastered eighteen languages. Michael Angelo at nineteen had attained a very high reputation. At twenty, Calvin was a fully-fledged reformer, and at twenty-four published great works on Theology that have changed the destiny of the world. Jonathan Edwards, at ten, wrote a paper refuting the materiality of the soul; and at twelve was so amazingly precocious that it was predicted of him that he would become another Aristotle. At twenty, Melancthon was so learned that Erasmus exclaimed, "My God! What expectations does not Philip Melancthon create!"

Causes of the Exceptional Longevity of Great Brain-Workers.

The explanation of the surprising longevity of great brain-workers is quite complex. The readiest answer to the problem would be that brain work is healthful; and that, therefore, the better the brain, and the harder it is worked, the longer the life of its possessor. Such a solution would not be entirely true; and if it were true unqualifiedly, it would clear up but one side of the question.

The answer is to be found, not in any single consideration, but in many, as follows:—

1. *Great men usually come from healthy, long-lived ancestors.* Longevity is a correlated inheritance of genius. In order that a great man shall appear, a double line of tough, more or less vigorous fathers and mothers must fight in the struggle for existence and come out triumphant. However feeble the genius may be, his parents or grandparents are usually strong; or if not strong, are long-lived. Great men may have nervous if not insane relatives; but the nervous temperament holds on to life longer than any other temperament. The great man may himself be incapable of producing other great men; in him indeed the branch of the *race* to which he belongs may reach its consummation, but the stock out of which he is evolved must be strong, and usually contains latent if not active genius.* Longevity is, of course, hereditary, like all qualities or tendencies of organised life; and if great men come from long-lived stock, this fact is one most potent explanation of their exceptional longevity.

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* That intellectual qualities are subject to all the laws of hereditary descent, so far as we know these laws, has been fully established by the researches of Galton in England, and of myself in this country. I therefore assume the fact without argument.

2. *A good constitution usually accompanies a good brain.* The cerebral and muscular forces are correlated. This view, though hostile to the popular faith, is yet sound and supportable. A large and powerful brain in a small and feeble body is a monstrosity. "In monstrosities Nature reveals her secrets," says Goethe. When a specially small and delicate frame sustains a specially large and potent brain, men wonder, as at a tree bowed to the earth by the weight of its over-abundant fruit. Everywhere Nature is a slave to the necessity of correlation or correspondence of parts and organs with each other; and unless she heeds it, all organised life would become awry and misshapen. In all the animal realm, there is a general though not unvarying relation between the brain and the body of which it is a part and to which it ministers. A hundred great geniuses, chosen by chance, will be larger than a hundred dunces anywhere—will be broader, taller, and more weighty. In all lands, savage, semi-civilised, and enlightened—the ruling orders, chiefs, sheiks, princes by might and mind, scientists, authors, orators, and great merchants, weigh more than the slaves, peasants, and riff-raff over whom they rule; and bear the evidences of their superiority so clearly that they need no other insignia. In any band of workmen on a railway, you shall pick out the "boss" by his size alone, and be right four times out of five. Those monstrosities where genius is cabined in a small body show the law by their very rarity.

3. *Great men who are permanently successful have correspondingly greater will than common men; and force of will is a potent element in determining longevity.* The one requisite for great success is "*grit*;" and, more uniformly than any other single quality or combination of qualities, it is found in those who attain high distinction. In the grand struggle for existence, it is everywhere the stiff upper lip that conquers; the timid and the yielding are cowed and crushed, and over them rise the courageous and the strong. In certain special lines, as poetry and art, extraordinary gifts may, as it were, draw their possessor into fame with but little effort of his own; but the highest seats in the temples both of art and poetry are given only to those who have earned them by the excellence that comes from *consecutive effort*, which everywhere tests the vital power of the man. That longevity depends not a little on the will, no one will dispute. The whole subject of the relation of mental character to longevity is one of vast interest, and is too far-reaching to be here discussed; but this single point

must be granted without argument, that of two men every way alike and similarly circumstanced, the one who has the greater courage and grit will be the longer-lived. One does not need to practise medicine long to learn that men die that might just as well live if they resolved to live; and that myriads who are invalids could become strong if they had the native or acquired will to vow that they would do so. Those who have no other quality favourable to life, whose bodily organs are nearly all diseased, to whom each day is a day of pain, who are beset by life-shortening influences, yet do live by grit alone. Races and the sexes illustrate this. The pluck of the Anglo-Saxon is shown as much on the sick-bed as in Wall Street or on the battlefield. During the late war, I had chances enough to see how thoroughly the black man wilted under light sickness, and was slain by disease, over which his white brother would have easily triumphed. When the negro feels the hand of disease pressing upon him, however gently, all his spirit leaves him. The great men of history are as much superior in their will-power to the average of their fellows, as are the races to which they belong to the inferior and uncivilised races. They live, for the same reason that they become famous. They obtain fame because they will not be obscure; they live because they will not die.

4. *Great men work more easily than ordinary men.* Their expenditure of force to accomplish great things is less plenteous than the expenditure of ordinary men to accomplish such things. A Liverpool draft-horse draws with ease a load at which a delicate racer might tug and strain without moving it. Ruskin is quite right when he says that the greatest work is done easily. The best action is the unconscious. It is the essence of genius to be automatic and spontaneous. The common mind cannot attain this spontaneity, or at any rate only to a slight degree. Many a huckster or corner tradesman expends each day more force on work or worry than a Stewart or a Vanderbilt. It is notorious that Beecher's great sermons cost him only an hour's musing or so, while many country pastors work for a week over "efforts" that suggest no thought, except pity for the composer. Great genius is usually industrious, for it is its nature to be active; but its movements are easy, spontaneous, joyous. There are probably many school-boys who have exhausted themselves more over a prize composition than Shakespeare over "Hamlet," or Milton over the choicest passages in "Paradise Lost." At one time I acted as surgeon on a gunboat of the United States Navy on the blockade, which was under

the command of a man who, I am sure, worried and exhausted himself more over that little craft than did Admiral Farragut over the entire squadron. When he died, shortly after the close of the war, I was requested by his widow to use my influence in procuring a pension for her. This I was able to do most conscientiously, for I knew that he had worn himself out in the service, although the vessel under his charge, while I was on board at least, never went into action, chased no blockade runner, and experienced not one moment of real peril.

5. *The advantages that belong to the brain-working orders in general.* Of these I have already spoken in some detail. The great brain-workers of the world have not all been rich; neither have they all been poor; some of them have lived a portion of their lives, but very few all their lives, in extreme want; and the majority have been most of the time surrounded with at least moderate comforts.

Causes of the Great Longevity of Clergymen.

When, in 1867, I first called attention to the fact that clergymen were longer lived than any other class of brain-workers, serious doubt was expressed whether there might not be some error in my statistics. So much had been said of the pernicious effects of mental labour, of the ill-health of brain-workers of all classes, and especially of clergymen, that very few were prepared to accept the statement that the clergy of this country and of England lived longer than any other class, except farmers, and very naturally suspected a lurking fallacy. Other observers, who have since given special attention to the subject, have more than confirmed this conclusion, and have shown that clergymen are longer-lived than farmers.

The Rev. Josiah F. Tuttle, D.D., President of Wabash College, Indiana, has ascertained the ages of 2442 clergymen—600 Trinitarian Congregationalists, 317 Presbyterians, 231 Episcopalians, 268 Baptists, 208 Methodists, 166 Unitarians, &c.,—and found that the average was " a little over 61 years." " Considerably over one-half of the whole were over 60 years of age at their death; three-fourths of the whole were over 50 years old at death; and seven-eighths of the whole were over 40 years of age at death." Dr. Tuttle found that the average age at death of 408 individuals (not clergymen), and who had died over 21 years of age, was a little over 51 years. This result pretty nearly corresponds with mine.

But by far the more thorough investigation on this subject, and one that must fully settle the question for all minds over whom facts have any influence, has been recently made by the Rev. J. M. Sherwood, formerly editor of " Hours at Home," and now Secretary of the Society for Promoting Life Insurance among Clergymen. This gentleman has laboured long and patiently in this department, and has ascertained that the average age of our ministers at death is sixty-four. The report (I quote from Document No. 3 of the Society) states: "this is four years more than the longevity of the most favoured (?) class; ten years more than in the other professions: and from twelve to nineteen years above that of mechanics, artisans, miners, operatives, and the like."

These conclusions differ slightly from mine, but the difference is in favour of clergymen. Mr. Sherwood informs me that he had obtained the average from a list of ten thousand clergymen, whose ages at death he ascertained at great labour by consulting " the minutes of ecclesiastical bodies for thirty years past, the catalogues of theological seminaries, Wilson's " Historical Almanack," Dr. Sprague's " Annals of the American Pulpit," biographical dictionaries, the files of religious journals, &c.

A list of ten thousand is sufficient and more than sufficient for a generalisation : for the second five thousand did nothing more than confirm the result obtained by the first. It is fair and necessary to infer that if the list were extended to ten, twenty, or even one hundred thousand, the average would be found about the same.

In England, also, clergymen live to a greater age than any other class. According to the report of the Secretary of the Clerical Mutual Life Assurance Society, the mortality is less than that in twenty other companies by a very important percentage.

Causes of the Exceptional Longevity of Clergymen.

The reasons why clergymen are longer-lived than any other class of brain-workers are these :—

1. *Their callings admit of a wide variety of toil.*—In their manifold duties their whole nature is exercised—not only brain and muscle in general, but all, or nearly all, the faculties of the brain—the religious, moral, and emotional nature, as well as the reason. Public speaking, when not carried to the extreme of exhaustion, is the best form of gymnastics that is known; it exercises every inch of a man, from the highest regions of the brain to the smallest muscle. In his public ministrations, in his pastoral calls, in his study, in his business arrangements, in his general reading, the

pastor exercises more widely and variously than any other calling.

2. *Comparative freedom from financial anxiety.*—The average income of the clergymen of the leading denominations of this country in active service as pastors of churches (including salary, house rent, wedding fees, donations, &c.), is between 800 dols. and 1000 dols., which is probably not very much smaller than the net income of all other professional classes. Further, the income of clergymen in active service is collected and paid with greater certainty and regularity, and less labour of collection on their part than the income of any other class except Government officials. Then, again, their income, whether small or great, comes at once, as soon as they enter their profession, and is not, as with other callings, built up by slow growth.

Worry is the one great shortener of life under civilisation; and of all forms of worry, financial is the most frequent, and for ordinary minds the most distressing. Merchants now make, always have made, and probably always will make, most of the money of the world; but business is attended with so much risk and uncertainty, and consequent worry, that merchants die sooner than clergymen, and several years sooner than physicians and lawyers.

By what I here say, I do not mean to give the impression that clergymen are properly paid: for it is thoroughly true, as was once remarked by a certain political economist: "We pay best,—1st. Those who destroy us—*generals*. 2nd. Those who cheat us—*politicians and quacks*. 3rd. Those who amuse us—*actors and singers;* and least of all, those who instruct us."

The average income of all classes in this country is small—about 700 dols. a year—and for the labouring classes not more than half that sum; and if the same efforts were made to obtain the details of the financial history of every family in the land, as has been done in the case of clergymen, there would be some very dreary reading.

3. *Their superior mental endowments.*—The law which I derive from the study of vital statistics is, that other conditions being the same, the greater and richer the brain, the greater the longevity.

Now I speak calmly and discriminately, and from a careful comparison of biographical data, when I say that the clergymen of this country—as represented by the Congregational, Presbyterian, and Unitarian denominations—have presented a higher average of the higher kinds of ability than any other equally large class, of any age or section, of recorded history.

During the past fifteen years there has been a tendency, which is now rapidly increasing, for the best endowed and the best cultured minds of our colleges to enter other professions, and the ministry has been losing while medicine, business, and science have been gaining.

4. *Their superior temperance and morality.*—Clergymen are more regular in their sleep, meals, and exercise than any other intellectual class; and are less exposed to injurious influences and contagious diseases than some other occupations. Very rarely, indeed, does a clergyman become grossly intemperate, or addicted to gambling, or to the exclusive and injurious pursuit of any animal pleasure.

III. ON THE CONDITION OF THE ATMOSPHERES OF THE PLANETS.

By E. NEISON, F.R.A.S., &c.

THE atmospheric conditions prevailing upon the planets of the solar system is a question of peculiar interest, for until these are thoroughly realised it is impossible to properly interpret the numerous observations of the physical condition of the planets. Moreover, seeing that in the great majority of cases, the observations deal only with variations in the appearance of the planet, and that these must arise almost entirely from atmospheric changes, the important bearings of the conditions regulating these is at once manifested.

The question of the height of the atmospheric envelope of the four great planets, Jupiter, Saturn, Uranus, and Neptune, derives peculiar interest from the influence it possesses over the physical constitution of the planet itself. It is known that the mean densities of these four greater members of the solar system are all very small, being in no case much greater than that of water, this peculiarity being of great interest and considerable importance in considering the probable physical constitution of these planets. It has long been suggested that this may be only apparent for the diameter of these planets measured, being that of the upper cloud-bearing strata of their atmospheres; if this be of great depth and yet of moderate density, the actual solid planet may possess a much greater mean density. If it be supposed in fact that the depth of the atmosphere was as much as one-tenth the apparent diameter of the planet, the mean density of this would be nearly doubled. It has been often urged, therefore, that the real average density of these planets may be much greater than that usually supposed, from their real dimensions being far less than their apparent; the augmentation arising from the presence of cloud-bearing atmospheres, that on Jupiter, it is assumed, may be as much as eight to ten thousand miles in depth. But no attempt appears to have been made to ascertain how far these supposed great depths of cloud-bearing atmosphere are consistent with those known dynamical laws which inflexibly sway the condition of gaseous envelopes on the other planets beside the earth; or whether, to render such immense atmospheres possible on these giant planets, conditions must not be assumed that are inadmissible.

The laws on which the physical condition of the atmospheric envelope of any of the planets may be regarded as depending have been long known, and have been applied with tolerable success in obtaining an approximate acquaintance with principal variations in the atmosphere of the earth, and for the higher regions of the gaseous envelope of any planet the theoretical constitution may be considered to have been determined, in so far as its solution is reduced to the ascertaining of the value of a single constant. But no attempt seems to have been made to apply these results to other planets than the earth, nor have they been placed in a distinct and convenient form for this purpose. A sufficiently approximate form of these equations can be derived very simply, and, as will be shown, made to afford results of considerable importance in considering the true nature of the planetary atmospheres.

Let

a = Radius of the planet.

$g_0 \ \delta_0 \ p_0 \ t_0$ = Force of gravity, density, pressure, and temperature of the atmosphere at the surface of the planet, and

$g \ \delta \ p \ t$ = the same at a distance x above the surface.

Then—

$$d\,p = -\,g\,\delta\,d\,x \qquad \ldots\ldots \qquad (1)$$

and replacing g by it value $g_0 \dfrac{a^2}{(a+x)^2}$ and change the variable to s where—

$$s = \frac{x}{a+x} \qquad \ldots\ldots \qquad (2)$$

and (1) becomes—

$$dp = -g_0\, a\, \delta\, ds \quad . \; . \; . \quad (3)$$

From the theory of the expansion of gases

$$p = \delta \frac{p_0}{\delta_0} \frac{1+\varepsilon t}{1+\varepsilon t_0} \quad . \; . \; . \; . \quad (4)$$

and dividing (3) by this value of p—

$$\frac{dp}{p} = -\, g_0 \frac{\delta_0}{p_0}\, a\, \frac{1+e\,t}{1+e\,t_0}\, ds \quad . \; . \quad (5)$$

This is the differential equation between the pressure and height above the surface, and when integrated by substitution in (4) gives the law of decrease of density, with increase of height above the surface. This equation cannot, however, be integrated unless the manner in which the temperature varies with the altitude is known. For the present this may be assumed to be given by—

$$\phi'(s) = \frac{1+\varepsilon\, t_0}{1+\varepsilon t} \quad . \; . \; . \; . \; . \; . \quad (6)$$

and then very conveniently it may be considered that—

$$\phi(s) = \int \phi'(s)\, ds \quad . \; . \; . \; . \quad (7)$$

Substituting these values in (5) after integrating and determining the constant by the condition that $p = p_0$ when $s = o$; whilst replacing for brevity the ratio $\frac{\delta_0}{p_0}$ by ρ and (5) becomes—

$$p = p_0\, e^{-g_0 \rho\, a\, \phi(s)} \quad . \; . \; . \; . \; . \quad (8)$$

and by substitution in (4)—

$$\delta = \delta_0\, \phi'(s).\, e^{-g_0 \rho\, a\, \phi(s)} \quad . \; . \; . \quad (9)$$

These two equations, once the form of $\phi'(s)$ is known, are sufficient to entirely determine the normal physical condition of the atmosphere of any planet, in so far at least as depends on variations indensity, pressure, and temperature.

As the expansion of gases for a small increase of heat is very small, for conditions when the atmosphere undergoes only slow and slight variations in temperature as the height above the surface increases, the law of decrease of temperature possesses only secondary importance, and the condition of the atmosphere of the planet approximates to that it would possess were the temperature throughout uniform. For many purposes it may, indeed, be considered that the temperature of the atmosphere is constant without introducing any very material error, especially in the higher regions, where the decrease of temperature must be so slight as to approach very closely to this condition. This condition is, in fact, as far as any of the planets of the solar system are concerned, the limit on this side to any possible constitution an atmosphere can possess; and as it reduces the equations to their simplest form for the purpose of ascertaining the extreme in this direction, this condition may first be supposed to hold.

Assuming that the temperature is constant and equal to t_0 then $\phi'(s)$ becomes unity and $\phi(s) = s$, whence substituting these values in equations (8) and (9), the two equations become identical and can be expressed as—

$$\frac{p}{p_0} = \frac{\delta}{\delta_0} = e^{-g_0 \rho a s} \quad . \quad . \quad . \quad . \qquad (10)$$

For atmospheric air it has been ascertained that—

$$\rho = \frac{0{\cdot}20131}{1 + \varepsilon\, t_0} \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

and for any other gas it can be found by dividing this by the specific gravity relative to air of the gas in question. Computing the value of the coefficient of s for the six planets, Mercury, Venus, Mars, Jupiter, Saturn, and Uranus, and denoting by T the quantity $1 + \varepsilon\, t_0$ then the coefficient $\beta\, T^{-1}$ of s on the six planets will be, on—

Mercury $\beta\, T^{-1} = 0{\cdot}0086\ .\ T^{-1}$
Venus ,, $= 0{\cdot}0671\ .\ T^{-1}$
Mars ,, $= 0{\cdot}0246\ .\ T^{-1}$

and on—

Jupiter $\beta\, T^{-1} = 2{\cdot}150\ .\ T^{-1}$
Saturn ,, $= 0{\cdot}860\ .\ T^{-1}$
Uranus ,, $= 0{\cdot}344\ .\ T^{-1}$

The planet Neptune has been omitted from its great resemblance to Uranus, which renders the physical conditions regulating the atmospheres of the two planets almost identical.

The length in miles of a unit of s on the different planets has, for convenience, been taken so that n units of s will, in miles, on—

Mercury $= 0{\cdot}148 + 0{\cdot}00002\, n^2$
Venus $= 0{\cdot}376\, n + 0{\cdot}00004\, n^2$
Mars $= 0{\cdot}246\, n + 0{\cdot}00003\, n^2$

whilst as on the larger planets the second term will be always insensible, it may be considered that on—

Jupiter $= 4{\cdot}30\, n$ miles.
Saturn $= 3{\cdot}60\, n$ miles.
Uranus $= 1{\cdot}65\, n$ miles.

Moreover, as on the larger planets the depth of the atmosphere is to be measured, these values become rigorous.

Keeping for the present to the group of the three greater planets, Jupiter, Saturn, and Uranus, supposing the density of the upper limit of the cloud-bearing strata of the atmospheres of these planets to be known, it would be easy to compute at what depth beneath this the superincumbent pressure would be so increased as to crush the gases forming the atmosphere into so dense a condition that they would become, to all intents, liquids; though probably long before this could be accomplished the atmosphere would have come to an end through the condensation of its constituents. The measured diameter of Jupiter and, as far as can be ascertained, of Saturn and Uranus, isth at of the upper limit of the cloud-bearing strata of their atmospheres; and, consequently, at this point the density cannot be of extreme slightness, for masses of condensed vapours or clouds can only exist and remain suspended in a strata of comparative density. In fixing the limiting density, where clouds may be considered as possibly existing, at as low as one-thousandth of the surface density of the earth's atmosphere, an extreme value is probably taken; for not only is it questionable whether any mass of brilliantly illuminated condensed vapour could remain in suspension in air of this rarity, but it is doubtful whether condensation must not always ensue before reaching so low. Assuming, therefore, this limit, it remains to consider the maximum depths of the atmospheric envelopes of the three great planets; supposing the lowest limit marked by the point where the gaseous constituents would be crushed by the superincumbent pressure into a consistency which would class them amongst liquids, not gases, even were they not actually liquefied long before reaching this point. Supposing that the temperature of these three planets is, like our own, not materially different from +100° to −100° C. the atmosphere may be considered as possessing uniform temperature of 0° C.

On Jupiter at a depth of only 19 miles the density would be already over ten times as great as our own; at 28 miles it would be denser than water, and at 33 miles as dense and heavy as mercury; though long ere this the immense pressure would have, through liquefaction, put an end to the atmosphere and the laws of gaseous compression. On Saturn the same points would be reached at a depth of 38, 57, and 68 miles; and on Uranus at 41, 66, and 77 miles below the visible cloud surface. These comparatively trifling depths under the supposed conditions are the maximum that the cloud-limited atmospheres of these three giant planets can possess; and their insignificance is such that on the limb they would subtend an angle such a minute fraction of a second of arc as to be almost undetectable and quite unmeasurable. Yet as far as the observed phenomena of the cloud belts of Jupiter are concerned, the depth is ample to explain all that has yet been definitely ascertained. Considering these three planets from the point of view that has hitherto been adopted, these may be regarded as the maximum depths of their cloud-bearing atmospheric envelopes, because any law of decrease of temperature that may be adopted will be without sensible effect on these results. But there is another point from which Jupiter at least may be regarded, and which considers that perhaps this giant planet may have retained sufficient heat to entirely remove the conditions prevailing on its surface from any analogy in point of temperature to those on the earth. It has been urged with much force that, from its great mass, Jupiter may have been much longer in cooling down than the earth and other smaller planets, and that, therefore, its surface temperature may still be very high; perhaps approaching or even reaching a low red heat. Under these conditions the law of decrease of temperature rises so much into importance that it cannot remain neglected, as has hitherto been done; but some attempt must be made to take it into account. The researches into the spectrum of Jupiter show that the greater majority, if not all, the light it sends to the earth, is merely reflected sunlight that has traversed a sufficient layer of atmosphere to exhibit absorption lines which indicate the presence of aqueous vapour. Had Jupiter been actually incandescent, that is to say were its surface, which can be probably seen through the clouds environing it, so intensely heated as to become white hot, a very different result would have been expected, and only one uniform mass of permanent dense cloud would be shown by Jupiter. Moreover, the formation of persistent marking in the visible surface of the planet, the arrangement noticeable in their form and position, and their appearance all appear more consistent with a moderate surface temperature, and could hardly be expected to be screening a white-hot incandescent planet. Some striking evidence of the vast energies at work could not but become manifest in a most marked manner were the entire surface of Jupiter one molten and seething mass of fire, as such a supposition would render it, whilst the environing vapours would become the scene of titanic throes from the alternate decomposition and re-combination of those energetic elements whose most stable combinations would be destroyed by the great temperature at the surface, to reunite on ascending to the cooler strata, only to be again dissociated on sinking towards the surface.

If, therefore, it were assumed that the surface of Jupiter might be so intensely heated as to reach a temperature closely approaching a white heat, say 1100° C., an extreme view of the possible high temperature of Jupiter would have been taken, and the resulting depth for the atmosphere of Jupiter may be regarded as the maximum present under even these conditions. It would only remain, therefore, to frame some probable law of the decrease of temperature of the atmosphere from the surface, for it is impossible that the air could remain throughout at this great temperature; but seeing how quickly gases cool under the condition they exist under when forming portion of the upper strata of the atmosphere, a very rapid degree of cooling might be expected when at a little distance from the surface. The actual law of decrease of temperature is of course unknown but sensibly, except close to the surface; the results obtained by employing any approximate law will give results sensible the same as the true, for the purpose in view here, as well as for most others, including the computation of the refraction. In framing such a law it will be necessary to put it into such a form that it can be readily applied without alteration, not only to different views of the conditions prevailing upon any one planet, but to those upon the whole six. The temperature of any strata of an atmosphere must be held to vary in some manner inversely as its density, this law regulating implicitly not only the conduction but the absorption of heat, as well also as the radiation, although not explicitly. It will also be apparent that close to the surface the temperature will decrease slowly, owing to the influence of the hot surface, and that, from exactly the reverse cause, the temperature towards the outer portion of the surface will vary with extreme slowness, the quickest decrease being in the central portion of the atmosphere of any planet.

Returning to equation (6), assume—

$$\phi'(s) = \left\{1 - f + f\,e^{-r\,u}\right\}^{-1} \quad . \quad . \quad . \quad . \qquad (12)$$

where u is a new variable introduced to retain the equations in a simple form, and such that—

$$g_0\,\rho\,a\,s = (1-f)\,u + \frac{1+r}{r}\left(1 - e^{-ru}\right) \quad . \quad . \qquad (13)$$

Differentiate this with respect to u, and after multiplying (12) by $\frac{ds}{du}$ integrate when—

$$\phi(s) = \frac{1}{g_0 \rho a}\{u - \log(1 - f + fe^{-ru})\}$$

substituting these values $f\,\phi'(s)$ and $\phi(s)$ in the two equations (8) and (9), and they become—

$$\frac{p}{p_0} = \{1 - f + f\,e^{-ru}\}\,e^{-u} \quad . \quad . \qquad (14)$$

and—

$$\frac{\delta}{\delta_0} = e^{-u} \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

Upon the values given to the two constants f and r will the rapidity and degree of decrease of heat depend, the former influencing mainly the amount and the latter more immediately the quickness of the decrease in temperature with the variation in density. To determine f, the condition exists that f must be such a value that at the summit of the atmosphere the temperature will be the same as the temperature of space; or if this be supposed extremely low, that at which the elasticity of the atmosphere is equalled by the attraction of gravity. Accordingly if t' be this temperature,—

$$f = 1 - \frac{1 + e\,t'}{1 + e\,t_0} \quad . \quad . \quad . \quad . \qquad (16)$$

The other constant r can be determined if the temperature at any given great height were known; but this not being so, it must be arbitrarily fixed. It is noticeable that when r is unity, its influence vanishes, but as it approaches zero its influence is to make the condition of the atmosphere approach those of a uniform temperature; whilst as it increases from unity and approaches infinity, it gradually approaches the condition of an atmosphere of the uniform temperature given by—

$$\frac{1 + \varepsilon\,t}{1 + \varepsilon\,t_0} = (1 - f)$$

on a surface heated to t_0. In both cases it may be held to approach from the value unity the condition of a uniform temperature.

Consequently, as it is apparent for beyond any but small values of u, this variable is greater than $\beta\,s$; for any admissible assumed law of decrease of temperature, the density of an atmosphere at a given height is less than the condition of a uniform temperature. Therefore the maximum depth any planetary atmosphere can possess will be that when its temperature is uniform. Now, applying this to the three great planets, Jupiter, Saturn, and Uranus, and allowing that their surface may be so intensely heated as to be at a temperature of 1100° C., and the computation of their depths on the hypothesis of a uniform temperature will give their maximum depths.

On Jupiter, under these conditions, commencing from a point already mentioned, when considering their depth at a temperature near zero centigrade, then at 74 miles below the upper side of the visible cloud layers it would be ten times denser than our own atmosphere, at 110 miles compressed until denser than water, and at only 148 miles as dense as mercury; though, as before remarked, long before this could have happened, the condensation of its constituents must have occurred, as the whole ceased to be a gas. On Saturn, the depths beneath the surface, where the same would occur, would be 154, 231, and 308 miles, and on Uranus 178, 268, and 357 miles. The telescopic insignificance of the depths, in mere dimensions, of the greatest of these three quantities on each planet is best shown by considering that on Jupiter it subtends an angle of only 0·06″ of arc, on Saturn of 0·08,″ and on Uranus of 0·04″—quantities unmeasurable, and almost invisible even in the finest telescopes. It cannot be supposed, however, that these dimensions, small as they are, can ever be reached by any of the three planets, for a temperature such as supposed could not extend undiminished to the outer limits of the cloud-bearing strata; and, therefore, to obtain in any way the probable depth of the atmospheres to these planets use must be made of equations (15) and (13). To take the most favourable circumstance possible, suppose the temperature never to fall below zero C., then the value of f from (16) for the supposed intense surface heat of the planets will be 0·80, whilst to give a very favourable condition to a great depth, make r instead of near unity only 0·20; so that temperature decreases so slowly as to be even beyond the summit of the cloud-bearing strata, the atmosphere will be of still considerable warmth. Then the three respective points already mentioned would, on Jupiter, be reached at a depth of 60, 72, and 78 miles; on Saturn, at 126, 152, and 164 miles; and on Uranus at 144, 173, and 188 miles respectively, or scarcely one-half of that found on the previous assumption. These depths appear, therefore, to be the maximum possible on any permissible condition on these three giant planets of the solar system.

There is at present no reason for believing that the atmosphere of Jupiter possesses a greater depth than from 25 to 50 miles; the only observation that can be considered as indicating any very much greater depth being those of the form of the shadow of the satellite, which though highly interesting, cannot legitimately be regarded as pointing in this direction. Whatever, therefore, may be held to be the cause of the slight mean density of Jupiter and its companions in this respect, Saturn, Uranus, and Neptune, it cannot arise simply from their possessing an immense depth of atmosphere.

There is one other point in connection with the atmosphere of Jupiter requiring examination, namely, the influence of the presence of an atmosphere on the occultations of its satellites; for if a fringe of atmosphere of any recognisable breadth were present, the satellites, instead of disappearing sharply behind, and re-appearing as distinctly from beyond the planet's limb, would fade slowly away. Thus from the effects of its refracting the rays of light, it would appear that if any considerable layer of atmosphere to Jupiter extended beyond his disc formed by the cloud strata, it could not fail to be recognised by retarding occultation and eclipses, and accelerating the re-appearances. With sufficient approximation, the horizontal refraction for any layer of Jupiter's atmosphere assumed similar to our own and whose density is δ_0' would be—

$$r_0 = 3{\cdot}0^\circ\ \delta_0'$$

Accordingly, for a strata of air only one-thousandth the density of our own the horizontal refraction would be still strongly marked.

In all probability the real density of the strata of Jupiter's atmosphere immediately beyond the uppermost clouds is in density over one-tenth of our own, and would, therefore, exert a horizontal refraction equal to half of our own, and be therefore most marked. The true reason of its being undetectable consists of the very slight breadth of the fringe of atmosphere from its very quick decrease in density, so that only twenty-four miles beyond the upper cloud layers of Jupiter's, the density of the atmosphere would be utterly insensible, and with it the horizontal refraction. As this distance of twenty-four miles would at Jupiter's distance subtend an angle of barely one-hundredth of a second of arc, whatever changes might be produced by it would be entirely unrecognisable; so that whatever may be the density of its atmosphere, the effects of the refraction of light through it would be entirely undistinguishable from the earth. And the entire absence of any detectable retardation of the occultation of Jupiter's satellites is in itself sufficient to show the absence of any great depth of atmosphere; for if the increase of density was so slow as to admit of this, the decrease beyond the cloud layers would be sufficiently slow to admit of the refraction being detected.

There is one point in connection with the maximum depth of the atmosphere of Jupiter that requires further attention, and that is certain phenomena seen during the transits of the shadows of the satellites across the planet. By numerous observers it has been noticed that occasionally the form of the shadow is not a black circle, but a slightly elongated ellipse, which though it has been estimated to be as much as half as long again as broad, probably is very rarely so markedly elongated, but that from the character and very delicate nature of the observations, the ellipticity has been as usual considerably over-estimated. It has been noticed that this elongation only occurs when the planet is near quadrature, so that the shadow on Jupiter is seen from a point inclined at a considerable angle to the axis of the cone of shadow.

It has, however, been considered* that this indicates a peculiar character and great depth in the atmospheric envelope of this giant planet, and from a series of nine rough estimates of the amount of this elongation, an attempt has been made to deduce the depth of the atmosphere of Jupiter by assuming the cause of this appearance to be due to the passage of the shadow cone, though a multitude of very thin, delicate, almost translucent clouds, suspended in the atmosphere of Jupiter. For assuming the atmosphere of this planet to be filled with delicate clouds of this nature, and so extraordinarily transparent as to permit shades to be visible through immense thicknesses of it, it can be shown that when Jupiter is near quadrature, the shadow column of the satellite will appear as an elliptical dark spot, with an equatorial penumbra. Supposing these conditions to hold, from nine observations the depth of the atmosphere of Jupiter is shown by a rough method to vary in minimum depth from 3200 to 9200 miles, the mean of nine estimates being 5400 miles. Even granting that the constitution of the atmosphere supposed in this hypothesis can be considered conceivable, and crediting the atmosphere of Jupiter to be filled with delicate clouds sufficiently transparent to enable graduation of shadow to be distinctly visible through an immense thickness that must generally be 5000 miles, though at times nearly 15,000 miles in depth, this explanation for the cause of the elongation is scarcely satisfactory, as no account is taken of the changes that must occur in the progress of the shadow across the disc. But apart from this, the supposition of such an immense depth of semi-transparent atmosphere is only possible if the surface of Jupiter possesses the tremendous temperature of 150,000° C. —a degree of heat impossible to realise; and that must render Jupiter a rival to the sun in intrinsic brilliancy. Now, the ground on which this hypothesis rests, which, considering the very small number of observations must be held to be extremely slight, may be divided into two: first, the equatorial penumbral fringe, and secondly, the elongation of the shadow. With regard to the former, as the true penumbræ of the shadows of the satellites is very considerable, being in the case of the nearest satellite nearly as broad as the dark shadow, whilst in the case of the farthest it is nearly four times as broad, and yet is rarely distinctly to be seen, any penumbral fringe that may be detected cannot be well distinguished from the effects of the true penumbræ; whilst the action of the atmospheres of the planet's satellites must still further complicate the appearance of the shadow. As far, therefore, as any deduction made from the presence of a penumbral fringe under these conditions, unless it could be shown that the appearances were independent of the true and atmospheric penumbræ, no legitimate conclusion could be drawn. But from the great variability in the size of shadows of the satellites on different occasions, it is known that the penumbral fringe must be variable. As there must be a penumbra entirely round the satellite, the mere inability on certain occasions to detect it near the Polar region cannot be held to show much.

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* BURTON, M. N. Roy. Ast. Soc., vol. xxxv., p. 65.

It can, however, be easily shown that when Jupiter is in quadrature the true form of the shadows of its satellites is elliptical without resorting to any hypotheses of an extraordinarily translucent and deep atmosphere. For taking the most unfavourable case of an equatorial transit, and putting θ for the Jovian ecliptical longitude of the shadow, measured from the point where the sun is in the zenith, and considered positive towards the east, then denoting by θ_1 the ecliptical longitude of the centre of the earth, the length of the shadow of the satellite as seen from the earth will be obviously

$$\int_{\theta'}^{\theta''} \cos(\theta-\theta_1)\, d\,\theta = \sin(\theta''-\theta_1) - \sin(\theta'-\theta').$$

where—

$$\theta'' = \sin^{-1}(\sin\theta + d)$$
$$\theta' = \sin^{-1}(\sin\theta - d)$$

d being the radius of the shadow. The breadth of the shadow will be obviously equal to $2d$. Now, considering the mean radius of the shadow to be half a second of arc under these conditions when $\theta = 9^\circ$ (for its maximum value 11° it will be much greater), the ratio of the equatorial diameter of the satellite to the polar will be, when the centre of the shadow is in the following apparent ecliptical longitude,—

$+80^\circ = 1{\cdot}90$ $\quad -75^\circ = 0{\cdot}40$
$+60^\circ = 1{\cdot}27$ $\quad -60^\circ = 0{\cdot}71$
$+45^\circ = 1{\cdot}15$ $\quad -45^\circ = 0{\cdot}84$
$+30^\circ = 1{\cdot}07$ $\quad -30^\circ = 0{\cdot}90$

The apparent centre of Jupiter being in $+9^\circ$, of course all the positive longitude must be diminished by 9° and the negative increased by 9° to obtain the position relative to the apparent centre of the disc. It is evident, therefore, that for nearly two-thirds of its course after entering the disc before reaching the centre the shadow will appear as an ellipse, the elongation gradually diminishing. Near the centre it will be circular, and for about one-third of the final half of its passage elliptical in the reverse direction. These variations have been detected with a six-inch equatorial during this year; though the equatorial penumbral fringe which must necessarily be present has not been distinctly seen, probably on account of its exceeding delicacy.

Comparing the effect of this cause with the only six cases mentioned definitely in the paper referred to,* it appears that in four of these the ellipticity arising from this case must have been sufficient to render it distinctly visible; in one case the shadow was round, and in the other most markedly elliptical in the reverse direction to that seen. As under any conditions these variations must be undergone, the effect that they would have in combination with the hypotheses assumed, would be to make the dark shadow to all intents vanish on occasions before reaching the limb of Jupiter—a fact in itself sufficient to condemn the hypotheses. But other causes might readily produce the effects noticed, especially the clouding of the atmosphere of the satellites, whilst the extraordinary irregularities undergone by the satellites themselves show the uncertainty that must attach to such extremely delicate observations.

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* M. N., vol. xxxv., p. 65.

There are other points of some question in connection with the condition of the atmosphere of Jupiter, more especially the shading noticed by Brett, Knobel, and Lassell on some of the minute white cloud-like spots. These appearances are, however, far from inconsistent with a moderate depth of atmosphere, such as it has been shown can well be supposed to exist on Jupiter. But in these, as in all other points, it is impracticable to found any trustworthy conclusion on so few observations as a score or so, and numerical data must be based on actual measures, for estimations on these delicate points can never be satisfactory.

In considering the probable atmospheric conditions of the three smaller planets less uncertainty with regard to the two principal unknown quantities exist, for not only is there no reason for believing that the temperature of these three planets differs materially from that of the earth, but neither can the density or nature of their atmospheres. Their comparative nearness also allows of telescopic investigation, affording a considerable amount of information with regard to their probable condition; whilst their astronomical character indicate a great analogy in constitution of the earth. It will, therefore, not be necessary to regard them from the extreme points of view necessary in dealing with Jupiter; whilst their proximity to the earth permits an additional method of obtaining information with regard to the atmospheres to be made use of, namely, its horizontal refraction.

Mars may be first considered as being the planet about whose physical constitution more information has been obtained, from telescopic and spectroscopic investigation, than any other. The appearance of Mars under favourable conditions is well known,—a distinct orange ground with faint shadings of brown, yellow, red, and grey, containing numerous permanent dull bluish grey markings, whilst the poles are marked by circular brilliant white spots. These last, from various considerations, have been, with justice, regarded as due to accumulations of snow and ice on the poles of Mars in the same manner as on the earth; and the dark bluish grey or, according to many observers, greenish spots appear to be true seas on Mars. The existence of an atmosphere to Mars has been demonstrated by telescopic observation, which has shown many clouds, but apart from this is a necessary corollary to the existence of moisture; and from the spectroscopic researches of Huggins and Janssen this atmosphere is very similar to our own, and according to the latter the presence of moisture is shown by its spectrum. Mars may therefore be considered to possess an atmosphere bearing a considerable resemblance to our own, though, from the small number of clouds and the general transparency, perhaps slightly inferior in density. The temperature at the surface is also probably very similar to our own, for the following reasons:—Were the temperature of Mars, in any marked degree, warmer than our own, from the presence of considerable bodies of water, an envelope of moisture of considerable dimensions would be formed, the polar ice zones would be much smaller, numerous clouds must at times occur, and the column of aqueous vapour traversed by the sunlight reflected from the surface of Mars would be so considerable, that the spectroscopic evidence of its existence would be of the most marked character.

Were, however, the temperature in any degree much colder than our own, the seas of Mars would be permanently frozen and snow covered; the general brightness of Mars being thus greater than the polar zones even, whilst the amount of aqueous vapour, though very variable, would be far too small to be revealed by the spectroscope, and clouds would be entirely absent. Only, therefore, if the temperature of Mars resembles that of the earth can its telescopic and spectroscopic characters be as they are. The conditions, therefore, of the atmosphere of Mars, in so far as its density and temperature are concerned, may be regarded as very similar to those of the earth; that is to say that its density is probably not over five times greater or five times less than our own, and its mean temperature at the surface within 40° C. of that of the earth.

Under these conditions the law of decrease of temperature of the atmosphere of Mars ceases to possess the all-important character it has when the variations in temperature are more marked, for the decrease must necessarily be, whether slow or quick, so small as to exert comparatively slight effect. The conditions are, however, sufficiently similar to those of the earth to render it probable that the law that best represents the rate of decrease of temperature on the earth will also best represent the same on Mars. In the equations (12), (13), and (15), putting $r=$ unity, and $f=\frac{1}{4}$, and they then reduce to the well known equations employed by Ivory, in his celebrated theory of the Astronomical Refraction, regarded by Plana and other eminent astronomers as best representing the condition of the earth's atmosphere. Substituting, then, the constant for Mars, and the height corresponding to any given density of the atmosphere of Mars will be found. From this it appears that, at a height of 8·59 miles, the density would be reduced to only half that at the surface; at the height of 15·84 miles, only one-fourth; at 24 miles, only one-tenth; at 44 miles, one-hundredth; at 64 miles, only one-thousandth; and at 130 miles, only one-millionth of that at the surface. When most favourably placed one second of arc at the distance of Mars is equal to 210 miles, and for a height of one-fifth of a second of arc at the limb the atmosphere would not be distinguishable from the surface of the planet. This corresponding to 42 miles, it is evident that nearly the entire atmosphere of Mars, at the limb, is so close to the surface as to be, to all intents, indistinguishable from it. This circumstance is important, for two occultations of stars by Mars have been seen when no trace of any retardation or distortion was observed, the star disappearing sharply and neatly at the limb. It has been considered that this indicates that the atmosphere of Mars must be of small density, or else the effects of its horizontal refraction would have manifested themselves. From the small diameter of Mars a horizontal refraction of only one four-hundredth the amount of our own would entirely prevent the disappearance of a star behind Mars, but would spread the rays into a distinct circle of light around the planet. But the breadth of the fringe of atmosphere being thus so small, only one-hundredth lying beyond one-fifth of a second from the limb, it is impossible to distinguish this circle of light, so that the star seems to disappear sharply at the limb, though in reality vanishing at a fictious border to the planet. To ascertain the effect of this small portion of the atmosphere beyond this distance from the limb, as the density of the atmosphere at this point is barely one-hundredth of that at the surface, the following approximate form of the equation to the horizontal refraction may be employed:—

$$r_o = 60{\cdot}6'' \, \delta_o' \sqrt{\frac{\beta\pi}{2}}$$

where r_o is the horizontal refraction and δ_o' the density of the air at the given point as compared with that at the surface of the earth.

Substituting the value of β and putting the density of the atmosphere at the point in question at only one-hundredth of that at the surface of Mars, the horizontal refraction, at a distance of only one-fifth of a second of arc from the true limb, would be—

$$r_o = 0{\cdot}34'' \, \delta_o$$

whilst at a distance of only one-third of a second of arc from the limb, it would be utterly insensible for any possible value of δ_0, the density of the atmosphere at the surface of Mars, which cannot be supposed to be much more than 5, but is probably slightly less than unity. A distance of one-third of a second of arc from the true limb of Mars is to all intents a quantity perfectly indistinguishable, for the irradiation at the border of the planet must usually exceed this, so that no effects of refraction from the atmosphere of Mars during an occultation of a star can be expected to be telescopically visible. It will also be apparent that extreme limits of what can in any sense whatever be held to be an atmosphere to Mars must lie within two-thirds of a second of arc from the true limb of Mars.

In certain features the atmosphere of Venus seems to present a strong contrast to that of Mars; thus on the latter extensive dense masses of cloud are very exceptional, but on Venus they appear to be the rule, so that it is seldom that the true surface can be distinctly seen, whilst the earth appears to possess intermediate features. The evidence establishing the actual existence of an atmosphere to Venus, though of different character to that referring to Mars, is yet even stronger, depending principally upon the effects of the refraction exerted by it. The first observation pointing to the considerable horizontal refraction of Venus was an observation by Andreas Mayer, who observed the planet when near inferior conjunction; the horns of the crescent being prolonged until meeting, the dark planet was surrounded by a ring of light, throwing the dark body into relief. Since then the planet, when near conjunction, has repeatedly been seen as a dark body surrounded by a bright ring; whilst the prolongation of the horns of the crescent planet has, under favourable conditions, been noticed by a number of observers since Herschel and Schröter. In 1849 Mädler, from a series of careful measures of the amount of this prolongation, determined that the horizontal refraction necessary to produce this was 43′ 42″. Lyman in 1866, from similar measures, found it to amount to 45′ 18″, and from a further series of observations in 1874 obtained 44′ 30″, on both these occasions seeing the dark body of Venus surrounded by a beautiful silvery ring of light. From these three series of observations the horizontal refraction of the atmosphere of Venus can be considered as determined to be 44′ 30″ with tolerable certainty, and the density of the atmosphere can therefore be determined with a considerable approach to accuracy; for the spectroscopic observations of Huggins, Janssen, and Vogel show that this atmosphere is essentially analogous to our own. The amount of the horizontal refraction, fully one-sixth greater than our own, indicates that the density of the atmosphere of Venus must exceed ours; whilst the dense mass of clouds, by retarding radiation, must render the decrease of temperature comparatively considerably slower, and therefore in computing the amount of the horizontal refraction due to any atmosphere this must be taken into account. It has been shown by the investigations of Laplace, Ivory, Bessel, and Lubbock, that the influence of the law of decrease of temperature on the amount of refraction due to an atmosphere of given surface density is of comparatively secondary importance, so that the uncertainty that must be considered to exist with regard to this point will not prevent a tolerably accurate value for the surface density of the atmosphere being obtained. The great similarity between the physical conditions prevailing on the surface of Venus to those on the earth, in as far as they effect the atmospherical laws, renders it probable that the law of decrease of temperature observed will not be materially different from that on the earth, though, perhaps, slightly slower, whilst the greater density and the number of clouds may, with the greater proximity of the planet to the sun, render the mean temperature of Venus sensibly greater than the earth's. Returning, therefore, to the series of equations (12) to (15) it is necessary to ascertain the horizontal refraction due to the passage of a ray of light through such an atmosphere. The long and complicated nature of this prevents this being effected here, owing to the very considerable amount of horizontal refraction rendering it necessary to take into account a whole series of terms not necessary even on the earth, and the resulting expression for the horizontal refraction contains no less than twenty-three terms. Supposing, however, the value of the constant f to be one-third, or slightly greater than on the earth, owing to the probably higher temperature of Venus, whilst putting $r = 0{\cdot}9$, so as to ensure a slightly slower decrease of temperature, then for a surface density the same as, and an atmosphere of similar nature to the earth, the horizontal refraction on Venus would be—

$$r_0 = 1733'' = 28' \; 53''$$

By assuming Ivory's theory to hold, the result would be 28′ 55″, or sensibly identical, though the rate of decrease of temperature is sensibly different. Bessel's hypothesis gives 29′ 9″, and the assumption of a uniform temperature which gives the maximum refraction 29′ 25″; showing the comparative slight influence of very different laws of decrease of temperature. Adopting 28′ 53″ for the horizontal refraction corresponding to a density equal to that of the earth's, the true surface density of the atmosphere of Venus obtained from the value 44′ 30″ for the horizontal refraction is = 1·546. This corresponds to a pressure (measured in the height of the barometer on the earth) of 1175 millimetres of mercury, or 46·4 inches.

The surface density of the atmosphere of Venus being thus determined, its variation with the height above the surface can be ascertained. At 3·67 miles above the surface the density would be only half that at the surface, at seven miles rather less than one-fourth, and at 11 miles only one-twelfth; which, corresponding to a height of nearly eight miles on the earth, would be probably the limit of the great dense cloud-bearing strata of Venus's atmosphere. At a height of 20 miles, the density of the atmosphere would be only one-hundredth that at the surface, a height of 30 miles would reduce it to one-thousandth, 39 miles to one-ten-thousandth, and 58 miles to one-millionth, where it may be regarded as sensibly becoming evanescent. Under the most favourable condition,—it requiring over 100 miles to subtend one-second of arc at the distance of Venus,—the insignificant nature of the breadth of the layer of the atmosphere of Venus is apparent, and the great difficulty of detecting it manifest. Ninety-nine-hundredths of the atmosphere of Venus lies within one-fifth of a second of arc from the limb of the planet, and is under ordinary conditions absolutely indistinguishable from it; and almost the entire remaining portion lies within half a second of arc, the whole atmosphere becoming sensibly evanescent at a distance of two-thirds of a second.

In occultations of stars by Venus—a phenomenon comparatively rarely visible—as no sensible refraction would ensue from the effects of Venus's atmosphere until the star was within a third of a second of arc from the planet, it would be utterly undetectable at that distance, for the brightness of the planet is so great as to cause an amount of irradiation at the limb far greater than this, so that the star would disappear at the bright fictious limb, as if no atmosphere existed; but at the dark limb of the planet under favourable conditions a beautiful and delicate ring of light might be momentarily detected flashing round the dark body of the planet before immersion.

Considerable discussion has arisen in connection with the observations of the late transit of Venus from the observation of a beautiful silvery ring of light around Venus during ingress, enabling the entire disc of the planet to be seen long before reaching the interior contact. This very delicate ring of light appears to have been considerably brighter than the sun's limb, and forming a fine brilliant very delicate line of light round the portion of the dark planet off the solar disc. Though this appearance seems to have been quite unexpected to the majority of the observers, it is a feature that the results of Mädler and Lyman showed might be expected, and appears indeed to have been recorded by several of the observers during the transits of Venus of the last century. There can be no question but that it arises from the horizontal refraction of the atmosphere of Venus, though not at first sight quite in accordance with the results already obtained with reference to the dimensions of the atmosphere of that planet; for although it has been shown that the thickness of the sensible atmosphere of Venus was only one-fifth of a second of arc, the breadth of this ring of light was estimated to be less than one-second of arc, or probably about two-thirds of a second of arc. It is manifest, however, that this so far from being inconsistent with the small breadth of the atmospheric zone of Venus is exactly what was to be anticipated for the effects of the spurious disc arising from diffraction, which would increase the apparent breadth of the line of light from a thickness of only one-fifth of a second to nearly one second. The superior brilliancy of the line of light around Venus to the limb of the sun is also easily understood, for it is well known that the solar limb is far inferior in brightness to the central portion; but the light refracted in any one direction by Venus is composed of rays from every portion of the solar surface, and consequently would be far nearer the brightness of the central portions of the solar disc than that of limb, and even allowing for a considerable amount of absorption by the passage through the atmosphere of Venus would be still superior in brightness to the limb of the sun. Moreover, as the horizontal refraction of Venus is so far greater than the semi-diameter of the sun, it is evident that the principal rays which pass through the extreme low-lying strata of Venus's atmosphere would fail to reach the earth when the planet was crossing the solar limb, from being refracted too much. It is easily shown that the horizontal refraction of Venus's atmosphere being nearly 45′, the principal solar rays refracted to the earth by Venus's atmosphere, when the planet was crossing the solar edge, would traverse the atmosphere of the planet at a height of nearly six miles above the surface, far above any surface vapours that alone powerfully diminish the solar light and pass through a column of atmosphere at its densest point, not one-half the density of the air near the earth's surface. The solar rays would traverse, therefore, the atmosphere of Venus with scarcely any diminution in intensity, and appear thus brighter than the dusky limb of the sun, and from the contrast with the dull orange or reddish tinge of the solar border appear silvery in hue.

The rapid disappearance of the very delicate line of light after the planet had left the solar disc is a phenomenon not very satisfactorily explainable, and must be regarded as presenting a difficulty. The brilliancy of the light refracted by the atmosphere of course very rapidly diminishes with the increase of distance from the border of the sun, both from a less amount of light being refracted and from its traversing a longer and far denser column of atmosphere; but this by itself is scarcely sufficient to account for its complete disappearance. The presence of clouds or mist in the lower lying strata of the planet's atmosphere is of course adequate to entirely account for the observed phenomena, and may well have been its origin; but still it can scarcely be regarded satisfactory to have to assume the existence of a convenient band of clouds where they were wanted, and nowhere else. Probably the disappearance arose partly from the weakening of the solar light, but mainly from the disappearance of the dark body of the planet, which, when visible, would at once direct the eye to the position of the delicate ring, and by contrast throw it strongly into relief, whilst, when this had to a great extent disappeared, the delicate ring of light would be a very difficult object to detect through a dark glass. That the ring of light had not disappeared is unquestionable; for it was seen perfect by Lyman with great distinctness (without a dark glass) five hours before ingress, and still in part a considerable time after the transit.

A point of some interest in connection with this silvery ring of light was its forming close to the pole of Venus a bright spot, according to the Australian observers, which it has been suggested may arise partly from a greater refraction, owing to the greater density of the colder atmosphere near the poles, combined with reflection from the snow or ice zone of the planet. If the atmosphere was fairly free from cloud towards the poles, something similar to this might be expected; for the Italian observers under Tacchini have ascertained the presence of moisture in the atmosphere of

Venus, showing the presence of seas, and rendering it probable that this planet, like the earth and Mars, must possess arctic and antarctic cold ice zones which, reflecting those rays refracted obliquely on them, would appear as a white spot.

To this refraction of the solar rays by the atmosphere of Venus may perhaps, in great part, the appearance of the planet when near conjunction as a black disc on a lighter ground be ascribed; the dark portion of the planet being defined partly by light refracted, and partly by light reflected, from the planet's atmosphere.

A feature of peculiar interest noticed during the late transit was a faint grey halo around Venus, perhaps ten seconds of arc in breadth, or over one thousand miles, and this appears also to be detectable in the photographs. That it could possess nothing in common with the bright extremely narrow line due to the refraction of the solar rays by the atmosphere of Venus its great size leaves unquestionable; for the atmosphere of Venus must be considered absolutely evanescent at only one-tenth of the breadth of this halo of dull light, whilst its having been photographed shows it is not a matter of contrast. It appears to have been only visible around the portion of Venus on the sun; but bordering the planet on the solar disc the photographs show an extra deposit of silver, probably in some way connected with this remarkable halo, though possibly this last may be, as suggested by Ranyard, of independent origin, it having been found during photographs of solar eclipses. From its small breadth the atmospheric fringe of Venus will exert so small an influence that there will be no need to take its effects into consideration in determining the solar parallax from the results of the late transit, except in considering the time of contact obtained by the use of the spectroscope. In these observations the effects of the refraction of the solar rays by Venus might, perhaps, be found to require attention in determining the instant of contact, and indeed, from these observations, an independent determination of the horizontal refraction might be obtained.

With regard to Mercury, the slight acquaintance with the appearance of this planet renders its probable atmospheric condition less certain than in the case of its two companions, Venus and Mars. Yet the presence of an atmosphere indicated by the observation of Schröter, Mädler, and Secchi, is fully confirmed by the bright, though extremely delicate, ring observed round the planet during its solar transits. Like Venus, the real surface of the planet appears covered with dense masses of cloud usually, and only very rarely can perhaps its actual surface be seen. Supposing the law of variation in temperature to be analogous to that on Venus, the rate of decrease of density on Mercury would be as under, being slower on this planet than any other in the solar system; and thus, were not the planet always in so close proximity to the sun, would render Mercury the most favourable member of our system to study atmospherical effects.

At a height of 11 miles the density would be halved, at 33 miles reduced to one-tenth, at 62 miles to only one-hundredth, at 90 miles to one-thousandth, and at 200 miles become utterly insensible. As under the most favourable conditions one second of arc at the distance of Mercury from the earth is over 200 miles in length, it is evident that on Mercury, as all the other planets, the border of atmosphere is so shallow that on the limb it would be to all intents perfectly undistinguishable. From grey spots that have repeatedly been seen by observers during the transits of Mercury on the planet, it is possible that the atmosphere of Mercury may be of very considerable density, so as from the combined effects of refraction and reflection to produce these otherwise inexplicable markings. And the supposed great density of Mercury's atmosphere receives some support from the rosy tinge of the planet noticed by De la Rue, and the ill-defined border detected by Secchi.

From the formulæ already given, by assuming other conditions to hold upon the planets besides those that have been adopted in the above, any possible atmospheric condition can be easily found, it only being necessary to suitably determine the several constants. It will, therefore, be possible to test any supposed condition by assuming it to hold, and ascertaining whether it infringes any of the theoretical conditions; but it will appear that the two extreme limits of an atmosphere to a planet of the solar system will lie between the two conditions of a uniform temperature and uniform density, the one giving the maximum and the other the minimum depth.

IV. THE POSSIBILITY OF A FUTURE LIFE.*

GREAT, even in this self-applauding nineteenth century, is the amount of man's ignorance, and over much that he is supposed to know there brood not a few clouds of difficulty and doubt. Still it cannot be denied that we have made some progress. In certain directions at least we have been able to trace out the limits within which the knowable is included. Even concerning the origin of things,—confessedly one of the most difficult of all imaginable questions—if we have not come to the exact truth we have been able to narrow the number of conceivable hypotheses and to strike out for ever not a few errors. A century ago it was still possible for any one so disposed to maintain that the earth and the sun as we now see them had existed from all eternity, and would continue such as they are for ever and ever. His views would of course have been denounced by theologians as heretical, and as opposed to the Christian code of Revelation, but on purely scientific grounds and by purely scientific methods he could not have been fairly confuted. Now, from our researches into the attributes of Force, no less than from geological investigations, all this is changed. We know that neither sun nor earth can have existed from all eternity. That both had an origin in time, and that both, in time, must come to an end, are truths as firmly grasped by men of science as is the rotation of the planets. We can no longer conceive of the sun as an infinite source of force which can go on for ever pouring light and heat into space without being exhausted. Nor have we now any longer a warrant for regarding it, according to the clever device of some literal interpreters of the Mosaic cosmogony, as a mere light-bearer—as a body dark and cold *per se*, but specially invested some time after its coming into existence with a luminous and thermic external stratum, or "photosphere." Nor if, leaving earth and sun out of the question, we turn our attention to the distant stars, do we fail there also to recognise marks of a beginning and an end. We see stars of a pure white lustre, others which, like our own sun, burn with a dimmer and yellower fire, and others darker still, which pour out a radiance coppery-red or greenish-blue. We have even within the short space of our scientific annals records of stars which have grown less bright, or which, like the lost Pleiad, have become invisible. We read of stars which have suddenly blazed up with an unwonted splendour and have after a time gradually faded away. These phenomena we can only interpret in a manner which foretells the ultimate fate of our earth, of its sister-planets, and of the sun itself.

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* The Unseen Universe; or, Physical Speculations on a Future State. London: Macmillan and Co.

Again, we cannot fail to perceive that there is in all the forces of nature a gradual tendency to an equilibrium. One day that equilibrium will be attained. The last weight will have reached its level. The last molecule of matter will have satisfied its strongest affinity. All parts of the universe will be equally hot, and no light-wave will cross the regions of space. All these considerations throw a valuable, though indirect, light upon the origin of the universe. They compel us to infer that not merely this or the other heavenly body as now existing cannot have existed for ever, but that the whole must have had a beginning,—that the day was when it had not yet originated.

Now there are, we know, three theories, and as far as we are able to imagine only three, concerning the origin of the universe,—the atheistic, the theistic, and the pantheistic. The first mentioned may be presented in a double form. Either it regards the universe as having existed from all eternity, or it considers it as having been self-created. In the light of modern science neither of these views can be pronounced tenable. Its present activity, as far as we know, gives the lie to its alleged infinite past. Nor can we conceive how a universal and equally diffused medium could at some given point of time suddenly differentiate itself and begin the process of world-building. Did the primal atoms or the ether possess such power it could not have remained latent.

One refuge indeed remains, but this is in its nature doubtful in the extreme. There *may* be some power by which this general tendency to an equilibrium is counteracted, and in such a case the universe as a whole may go on from eternity to eternity. But in all our researches we have hitherto met with no proof of its existence,—no trace of its operations. This may not indeed be held to justify us in absolutely denying the existence of such a power or such a process. But still less shall we be warranted in building upon it, as if demonstrated. The advocates of the atheistic hypothesis can surely not blame us if we here quote the old saying, *De non apparentibus et non existentibus eadem est ratio.*

Such, then, is one of the results of modern physical science that it has rendered the idea of an eternally existing, or self-created, universe well-nigh unthinkable.

But there is also another principle perhaps of even wider bearing than the idea of the conservation of force—a principle which has slowly and gradually attained recognition, and which is known to some as the Law of Uniformity and to others as the Principle of Continuity. This principle is at once valuable and dangerous, safe-guiding and misleading. Without it science would be impossible, but with it grievous errors may gain recognition. The danger of the principle is that every theorist pronounces events or facts that suit his views in perfect harmony with its requirements. "Continuity, in fine," say two able modern writers, "does not preclude the occurrence of strange, abrupt, unforeseen events in the history of the universe." The principle is commonly based upon our almost instinctive tendency to expect that what has happened once will, under the same circumstances, happen again. It is a curious fact that those least willing and able to recognise the law of uniformity, as a general principle, are often most premature in expecting the recurrence of any particular case. The very dog or cat whom you have once fed expects a repetition of the gift whenever you appear.

The authors just quoted place it, however, on a new and strange basis: "Assuming," they say, "the existence of a Supreme Governor of the Universe, the principle of Continuity may be said to be the definite expression in words of a trust that He will not put us to permanent intellectual confusion." We cannot see that the principle—common in its outlines to man and beast—can be fairly connected with the God-idea at all. Nor must it be forgotten that its general application has been strongly insisted on by atheists and pantheists, and as strongly resisted by theists as being inconsistent with the belief in a special Providence and in the efficacy of prayer.

This brings us to the interesting and subtle attempt made by the late Charles Babbage, in his "Ninth Bridgewater Treatise," to reconcile miracles with law by showing that they were not infractions, but cases foreseen and preordained after the manner illustrated in his calculating engine. But it seems to us that our confidence in uniformity is equally violated by any exceptional case, as far as we are concerned, whether such case has been pre-arranged by any higher power or not. If we had the misfortune to see on some particular day a solid block of iron floating in the Thames, our confidence in what is called "law" would be at an end. For we should never be able to foresee whether such a case—pre-arranged if you will—might not recur on any future occasion. If once you show to us solid iron swimming, the idea of specific gravity has no longer for us any meaning. Nor can we refrain from pointing out that events which seem to be departures from uniformity become rarer and rarer in the exact proportion as nations attain a higher culture, and as the facilities for recording occurrences become greater.

Upon the doctrine of the Conservation of Force and upon the Principle of Continuity there has been based a new and original attempt to prove modern science compatible with the teachings of Christianity.

Reconciliation between Religion and Science, we may here ask—wherefore? What legitimate ground is there for a disagreement between them? Let us bring up as arbitrator not the much-talked-of "intelligent foreigner," but that still more mythological being the inhabitant of another world,—if in virtue of recent interpretations of the Law of Continuity our passions are not now supposed to extend over the whole universe.* Let us ask him as touching this supposed need of a reconciliation. Might he not well reply that Religion and Science address themselves respectively to different phases of man's nature; that their ends and their functions are widely distinct, neither being able to supply the place of the other;—that even when regarding the same object or fact, they view it from different aspects.† Might he not tell us that in his interstellar wanderings he had met with a race equal or superior to ourselves intellectually and mighty in science, yet devoid of those emotions and passions which make up the main tissue of normal human life and to which Religion addresses itself? Might he not remind us that in the person of Henry Cavendish our own species had produced at least an approximate instance of such a being? On the other hand, he might describe to us creatures far inferior to man in intellect and incapable of that systematised interpretation of the universe which we call science and yet filled with an intenser moral life.‡ We do not think that it would be difficult to find examples of individuals,—perhaps even of races,—tending in this direction. There are, then, in mankind as it actually exists two types more or less strongly marked. On the one hand, we find the men of intellect, of speculation—using the term in its German acceptation—objective in their aims, and seeking every where for law and sequence. On the other hand, we perceive the men of moral, emotional life, subjective, craving in all things, and above all things for personality, will, purpose. The authors of the work before us recognise the existence of these two classes—or, better, two tendencies—under the names of followers of the "How" and disciples of the "Why,"—though they fail to see much which this distinction involves.

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* See Sir D. BREWSTER'S "Plurality of Worlds," *passim*. The same author in his inaugural address as President of the British Association in 1850 said:—"If men of ordinary capacity possessed that knowledge which is within their reach and had that faith in science (?) which its truths inspire, they would see in every planet around them, and in every star above them, the home of immortal natures, of beings that suffer and of beings that rejoice, of souls that are saved and of souls that are lost!"

† "The golden side of Heaven's great shield is faith; the silver, reason."—BAILEY'S "Festus."

‡ It will be understood that the term "moral" is not here used in antithesis to "immoral," which it in this sense includes, but in contra-distinction to "physical" and to "intellectual." It is well known that the religious world are generally more lenient to the man of strong, though ill-regulated, passions, than to one like Cavendish, whose moral nature is, so to speak, atrophied, and

We have, then, before us two variables, each of which may be increased or decreased without producing any corresponding or even inverse augmentation or diminution in the other; nay, either of which might conceivably be wholly wanting. Is not this proof sufficient of mutual independence, isolation? Our imagined visitor from Procyon or Vega might surely then declare that between tendencies both perfectly legitimate, yet at the same time mutually independent, collision cannot have arisen without the aid of much depraved ingenuity. Disputes between Religion and Science—or, in other words, between man the believer and man the discoverer—are about as rational as war between two sets of beings inhabiting different media, and each incapable of existing in the sphere of the other.

But unfortunately the Christian records, like those of various so-called Heathen systems, open with a cosmogony. Or let us rather say unfortunately ecclesiasticism will persist in treating this magnificent poem as a literal history. Upon this cosmogony, coupled with certain passages in the Hebrew and Greek Scriptures capable of being treated as astronomical, physical, geological, and biological utterances, it has founded a code of natural philosophy. To reject this code, or to bring forward either deductions or facts at variance therewith, it has anathematised as "infidelity." *Hinc illæ lacrymæ!* The quarrel, if quarrel it be, has been begun, not indeed by Religion, but by those who took upon themselves to speak in her name and defend her supposed interest. On the other hand, the followers of Science, not content with insisting upon their own rights, executed from

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whose life is free from all vices because the energies of his being are totally absorbed in speculative research. Said an eminent German Pietist, Count Zinzendorf:—"Between devotion and lust there is but one step."

time to time counter-raids, more or less injudicious—of which Dr. Tyndall's Belfast Address is one of the latest instances.

Now the way to end this fruitless feud is the simplest thing possible. Let both parties enter into a treaty of "let be for let be" as it is called in homely phrase. Let divines cease to judge scientific theories by theological standards, and to preach against the researches of Darwin. Let men of science, in turn, cease to proclaim everything non-existent and inconceivable which they cannot weigh in the balance or observe with the spectroscope. Let each, Religion and Science, be content to pursue its own objects by its own methods, and for the reconciliation of difficulties let both wait in faith. Such a settlement was first hinted at by Giordano Bruno and was advocated in full by Galileo in his celebrated letter to the Dowager Grand-Duchess Cristina of Tuscany. Here he contends that the Scriptures have no claim to be received as a scientific revelation; that on astronomical and physical questions,—to which we might now add geological and biological,—they convey merely the notions current at the times when they were written.

If we accept this view all difficulty is at an end. But there are many who seek to bring about a reconciliation, not by relegating Religion and Science each to its own department, but of bringing them into harmonious inter-dependence. Many have been the attempts made in this direction, agreeing perhaps in nothing save the unsatisfactory character of their results. Some have extracted systems of science from Hebrew roots under high-pressure philology, a mental diet analogous to the soup obtained from old bones in Papin's digester. Others have sought reconciliation by denying or explaining away the most elementary truths of science. As an instance of this method we may recall the existence of a book,—some few copies of which may have escaped the hands of the trunk-maker and the butterman—entitled "Errors in Electricity, Magnetism, and Chemistry," by a F.R.S. In this perhaps the only really noteworthy passage was the author's solemn confession that he had never made, individually or by proxy, a single experiment in any of the sciences for which he undertook to legislate.

The writers of the book before us are of a very different grade, and bring to their task far higher qualifications. They are beyond dispute men of science, well acquainted with the latest achievements of modern research and willing to accept them as true. They receive for instance the nebular hypothesis concerning the origin of the heavenly bodies,—a view not merely anathematised by divines, but which even a philosopher like Sir David Brewster could scarcely name with patience. They admit the still more dreaded doctrine of organic evolution, and do not even positively insist on the necessity of a special intervention for the origin of man. This is much. But they go still further; they distinctly formulate the view that man is not merely entitled, but even bound, to push back as far as possible all such Divine intervention.

We must beg our readers to make especial note of an admission so pregnant.

Nevertheless the writers are theologians even more decidedly than philosophers. They are at home in the sphere of the divine, and regard everything instinctively from his point of view. They are familiar with the Bible and with the views of commentators. They are versed in the mythology of all nations. "The existence of a Deity who is the Creator of all things" they "assume as absolutely self-evident,"—one of their critics remarking in reply that "it is evident" is merely another mode of saying "I do not know how to prove." But for all this we doubt whether religious orthodoxy will accept them as its duly authorised advocates and representatives. Their Deity, though tri-une, has a less personal and more pantheistic character than Christianity recognises. Nay, if we do not misunderstand the authors, they seem to surmise that the creation of the universe may have been effected, not by the Supreme himself, but by subordinate though still mighty agents. On the origin of Evil, also, their views can scarcely be accepted as orthodox. They regard it as "eternal," not confined to that planet which we inhabit, and they remark that "the dark thread known as evil is one which is very deeply woven into that garment of God which is called the Universe." They urge also that:—"The matter of the whole of the visible universe is of a piece with that which we recognise here, and the beings of other worlds must be subject to accidental occurrences from their relation with the outer universe in the same way as we are. But if there be accident, must there not be pain and death? Now these are naturally associated in our minds with the presence of moral evil."

Without entering into any criticism of the views thus expressed, we ask how they are to be reconciled with certain ordinary and supposed essential doctrines of Christianity? The Scriptures, it is generally conceded, teach that man was created immortal and perfect, in a perfect world, and that death, sin, and "all our woe" only entered through his disobedience. This is certainly not the place for a formal theological discussion, but it does seem to us that the authors, in surrendering the Fall of Man, have rendered a very questionable service to Christianity. This is a snare into which reconcilers are very apt to fall. They look attentively at the two theories, interests, parties, or the like which they would fain bring into accord. As they gaze the difficulties seem to vanish, and with a sincere Eureka, they turn to inform the world of their success. When, lo! it is found that they have harmonised, not what actually exists, but two creations of their own. They have made the boot fit the foot by liberally trimming and cutting both one and the other!

The immediate purpose of the work before us may be learned from its second title, "Physical Speculations on a Future State." The authors seek to show that immortality—a new life after the phenomenon known as death—is not impossible, and is not contradictory to, but rather in harmony with, the law of continuity. They declare that the "great mass of mankind have always believed in some fashion in the immortality of the soul; but it is certain that we may yet find disbelievers in this doctrine who yet retain the nobler attributes of humanity." The strength of this disbelieving minority they consider "has of late years greatly increased, until at the present moment it numbers in its ranks not a few of the most intelligent, the most earnest, and the most virtuous of men." To these accordingly they address themselves in the opinion that they are probably "unwilling disbelievers, compelled by the working of their intellects to abandon the desire of their hearts only after many struggles and much bitterness of spirit." Now we cannot, certainly, conceive the man or woman who does not crave for a further life, even for immortality.

Annihilation has no charms. We have read the "Logic of Death" of a celebrated sceptical writer, but it satisfies no one.* Yet even annihilation may not be the greatest conceivable evil. Our authors must know that many of the class for whom they write have been driven to the rejection of a future life less by the working of their intellect than by the revolt of their moral faculties. Such men,—we expound here without advocating their opinions,—much as they may shrink from an utter extinction of consciousness, look with far more loathing upon the future life of ordinary Christian eschatology—to wit, eternal torment for the many and a never-ending Sunday-school celebration for the favoured few. To such minds this prospect appears not merely inconceivable, but a libel on the Creator; and upon them, therefore, the argument of our authors, ingenious as it undoubtedly is, will be utterly thrown away. We must further call to mind that immortality, though an essential, is not a peculiar doctrine of the Christian religion, of which even its absolute demonstration furnishes no conclusive evidence. But no such demonstration is here attempted. We are reminded that the universal longing for immortality affords a presumption at least of a future life in which this yearning may be gratified. An eccentric friend of ours whose life has proved a failure, argued that this very craving is an evidence *against* immortality. But if it is an evidence of a future life at all, it must be taken in proof of a future of universal happiness. To implant such a craving, and then to fulfil it with an immortality of misery, would be more merciless than not to fulfil it at all.

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* "The Martyrdom of Man," by the late Mr. Winwood Reade, another book which seeks to reconcile man to the prospect of the utter and final cessation of consciousness at the moment of death, we must unhesitatingly declare one of the saddest works ever written.

The work before us, like certain recent legislative measures, is of a decidedly "permissive" character. It deals in the "may be" rather than in the "must be." It takes the conceivable as tantamount to the actually existing, and asks, "Is it not hazardous to deny?" where, to say the least, it is equally hazardous to assert. There is, we learn, around us, or among us, an "unseen universe." In density it bears about the same proportion to the interstellar, luminiferous ether which this does to ordinary molecular matter. From this unseen universe, or second ether, the visible universe and all that therein is originally proceeded, and into it they are being gradually re-absorbed. Beyond this second ether there is a third finer still, forming a second unseen universe, and beyond this another and another, each less dense than the preceding. These unseen universes, or at least the first of the series, receive the force which the ether loses. That such a loss takes place, the authors conclude from Struve's statement that there appear to be fewer stars of the tenth magnitude than should be visible if all their light reached us unabsorbed. The portion which thus disappears on the way is, they assume, taken up by the ether and handed over to the first "unseen universe." Of the properties and powers of this unseen universe we know, of course, nothing. When, therefore, the authors ask us in substance, "Why may it not" be the scene of the life to come, we are certainly unable to give any direct reply. For all we can show to the contrary, this second universe, if it exists at all, may contain anything. In this unknown and hypothetical region, a spiritual body—if such a term may be logically applied to what seems after all merely a matter extremely rarefied—is being elaborated for each of us after this fashion. Every thought or emotion which passes through our minds occasions, as is now generally admitted by physiologists, a certain molecular action in our brain. This action disturbs the ordinary luminous or interstellar ether, and a portion of such disturbance, like a portion of the light of the stars, is handed over to the second ether or unseen universe. By degrees, an organised structure is thus built up, though devoid of consciousness. When at last we die, our consciousness is, in some mysterious manner, transferred to this second body, and we begin a new life, though retaining our personal identity, and being mindful of all that has occurred to us in our present state of existence.

All this, the reader must carefully bear in mind, is supposed to happen, not by miracle, not in virtue of any direct interposition of God, but in obedience to the ordinary "laws of nature." Certain questions, therefore, arise, the answers to which are in the highest degree doubtful. That a molecular disturbance in the human brain may affect the ether, may be transmitted to an unseen universe, and may there produce physical effects, are propositions which we are not prepared to deny. But how are these effects to be localised and kept separate? We know that the light-waves thrown off from any illuminated body are capable of producing chemical effects upon certain substances, and of thus stamping the image of such body upon a duly prepared surface. But for this purpose care must be taken that the light-waves thrown back by other bodies do not interfere. If we place a sensitive paper, not in a camera, but in the open air, we do not obtain a landscape, but a blot. The undulations from each object do not select some part of the paper to impress themselves upon, but act indiscriminately upon the whole surface. What in the unseen universe is to play the part of the camera? How are the impressions emanating from the brain of each of the thousand millions of the human inhabitants of the earth—to say nothing of its brute population, and of the possible intelligences dwelling in other heavenly bodies—to be sorted out and compelled to act, each on the one spot required, and nowhere else?

The authors, indeed, make an attempt to meet this difficulty, an attempt so feeble that we marvel how it can proceed from men who elsewhere show themselves capable of reasoning most ably. They say, "We are as much puzzled by what takes place in our present body as we can be with respect to the spiritual. Thus let us allow that impressions are stored up in our brains, which thus form an organ connecting us with the past of the visible universe. Now thousands, perhaps even millions, of such impressions pass into the same organ, and yet by the operation of our will, we can concentrate our recollection upon a certain event, and rummage out its details along with its collateral circumstances to the exclusion of everything else. But if the brain, or something else, plays such a wonderful part in the present economy, is it impossible to imagine that the universe of the future may have even greater individualising powers? Is it not very hazardous to assert this or that mode of existence to be impossible in such a wondrous whole as we feel sure the universe must be?"

This illustration, we urge, is totally beside the question. An organism must exist before it can receive and individualise the impressions which occur. But here the organism has to be built up by the impressions themselves. Or, returning to our former illustration of the photographic camera, we know that it, with a duly prepared plate, can individualise into distinct images the light-undulations proceeding from bodies placed before it; but can we conceive of these undulations creating the camera and the plate on which they are to be recorded? For such a process we can find in the known universe no analogy. What it is possible for us to imagine is, we submit, quite unimportant. It may, indeed, be "very hazardous" to deny the possibility of anything. But is not the position of the authors still more hazardous? Before expecting our assent they are bound to produce some argument far more cogent than "why may it not?"

But the authors' entire line of reasoning, touching the unseen universe, is based upon doubtful assumptions, and is beset with difficulties little less formidable than the one we have just pointed out. Let us return to the fundamental fact, or alleged fact, of the small number of stars of low magnitudes. The calculation of Struve took for granted that the stars are uniformly distributed throughout space. This is a fallacy. The heavenly bodies within our range of vision belong for the most part to a single group, which appears to lie like an oceanic islet in vast starless regions. The interstellar spaces contain not merely the ether, but in all probability diffused gases, which may absorb the light of the more remote stars. The effect of the upper regions of our own atmosphere has also to be taken into account. It is further supposed by some that space may contain in considerable numbers the dead bodies of extinguished suns, which, of course, may eclipse to us the light of stars placed behind them. Hence there is absolutely no proof that any light is absorbed by the ether. The supposition of such a process is merely one out of several ways of accounting for certain facts, and it is in no manner forced upon our acceptance.

But supposing such an absorption to take place, is there any necessity that the force thus gained is handed over to an assumed second ether? None whatever: this force may, quite as probably, be restored to the visible universe in manners not dreamt of in our philosopy. An acute though sarcastic critic has pointed out that it may be transformed into other kinds of motion, or may serve in making up atoms, and even that the doctrine of the conservation of force may be only an approximate truth, and that the light, if any, absorbed by the ether, may be simply lost.

Among the possible objections to their views—it is curious, by the way, to note the kind of arguments which theorists put into the mouths of imaginary opponents,—we find it conceded that the unseen universe of the authors will find room for an immortality, not of man only, but also in brutes. How far down the organic series immortality is supposed to extend they do not say. Plants, indeed, have no brain and possibly no memory, but may not the same be said of many forms of animal life? We certainly should not object to the widest extension of a future existence. Flowers and trees are always pleasant companions, which is vastly more than can be asserted of animals, our own species by no means excepted.

But if we admit the unseen universe of our authors, and if we suppose our spiritual bodies duly elaborated there, and rendered the seat of the consciousness that has left its decaying tenement in this world, there is another difficulty remaining. How is our immortality in such future state to be guaranteed? Shall we be able to exert force without transformation of material, or, in other words, to create force out of nothing? This we have always held to be the prerogative of one only Being. But if not, will not the preservation of our life depend upon conditions strictly analogous to those by which it is governed in our present state? Nor is this all: by hypothesis our spiritual bodies will stand to their surroundings in a very similar relation to that which our present frames bear to the medium which they now inhabit. But if so, we may extend the argument which the authors have applied to the inhabitants of other orbs in the visible universe and we may in like manner infer that in the life to come we shall not be exempt from accident, and from its consequence—death. Possibly this point has been foreseen by the authors. Perhaps they may argue that if we die in unseen universe No. 1, we shall live again in unseen universe No. 2, and so on *ad infinitum*.

Now we are not aware that this supposition involves any new difficulties. Our transfer from No. 1 to No. 2 might be effected on the very same principles as our removal from this world to No. 1, and a virtual immortality, or at least continuity of consciousness, might thus be maintained. But such a future life would be reft of half its attractions. Is not the greatest pang of death the separation from those we love? Is not the hope of an eternal reunion the main source of our yearning for a life beyond the grave? But if such future life consists in a series of removals from one unseen world to another, the prospects of reunion become very slender.

The authors devote a chapter to discussing the possibility of intelligences superior to man existing in the visible universe. This inquiry seems at first glance irrelevant. But it is to some extent justified by the consideration that if such exist it might be "at least conceivable that man may be at death drafted off into some superior rank of being connected with the present universe, and thence ultimately removed into a new order of things when the present universe shall have become effete." The conclusion they reach is in the negative. Science tells us of no superior order of beings connected with the present universe, and in virtue of the law of Unity, they pronounce the conception of such beings altogether untenable." That beings analogous to man may exist in other worlds they do not dispute. Turning from the "verdict of science to the sacred writings of the Jews, we find," they continue, "that one grand idea which pervades the whole of the Old Testament is man's absolute superiority and practical sovereignty over all created beings whom he can perceive otherwise than with the *mind's* eye."

Now, that science has hitherto revealed to us no being superior to man is undeniable. But is it not "very hazardous" to conclude that none such may exist in other portions of the present universe? The authors admit beings "analogous to man," but a certain degree of analogy is not inconsistent with immense superiority. We know that the meteorites which from time to time fall to our earth have been found to contain no element hitherto unknown to us. We admit that the spectroscope points out to us in the sun and the fixed stars simple bodies, which, with the exception of helium, form part and parcel of our planet. We know that the most distant heavenly bodies are influenced by gravitation, light, heat, and probably by electricity and magnetism. But all this takes us a very little way towards ascertaining the nature of the living beings which may inhabit those orbs. To take an illustration from our own planet. We might find, say in Borneo, minerals very similar to those obtained in Australia. But would that warrant us in concluding that in Borneo the highest existing form of animal life was of the marsupial type?

Nor do we think that the Scriptures, Jewish or Christian, convey any decisive information on the subject. Concerning the population of other worlds in the present order of things, they are, we believe, totally silent. The sovereignty of the globe which they attribute to man, and the supremacy over all other visible and tangible beings thereon, are of a very doubtful nature. In how few parts has he succeeded in extirpating even the larger carnivora! How powerless is he in dealing with mosquitoes, locusts, and still more with those minute organisms believed to be the *materies morbi* of yellow fever, plague, and cholera! It may also be questioned whether the Scriptures do not grant the presence on the earth of beings heterologous to man, and possessing superior attributes. The idea of witchcraft is based upon the existence of such beings. Yet that the Bible recognises witchcraft not as an imposture but as a reality is admitted by theologians of repute. John Wesley declared that to give up witchcraft was tantamount to giving up the Bible. The General Assembly of the Church of Scotland denounced the repeal of the penal statutes against witchcraft as a national sin.

If, however, the authors consider man as belonging to the highest type of beings in the present order of things, they are of a different opinion as regards the unseen universe. This has its own population independent of the phantoms of men and animals who may have been transferred to it from worlds like our own. If we only suppose the unseen universe not separated from our world by distance, but interpenetrating its molecules, and thus being at once near us, and yet till death at least infinitely remote from us, we may here be reminded of some of the weird speculations put forward by the late Lord Lytton in his "*Zanoni*" and "A Strange Story." The "Dweller on the Threshold," and other beings, hideous or lovely, there represented as inhabiting the realms of space, are not spirits, but composed of matter so sublimated as to escape the senses of man in his ordinary condition.

The authors give it as their opinion that the "nebulous beginning and fiery termination of the present visible universe are "indicated in the Christian records." The "fiery termination" assigned to the world by the ordinary Christian eschatology does indeed present a certain superficial resemblance to what science points out as the probable ultimate catastrophe. But we must remember that certain sects of ancient philosophers held in like manner that the earth would ultimately be destroyed by fire, and that these views had been promulgated before the date of the New Testament. As to the "nebulous origin" of the universe, we may ask how is it, if such be the teachings of the Scriptures, that both divines and philosophers of orthodox tendencies failed to perceive it, and denounced the hypothesis of Laplace as essentially atheistic? Thus Sir D. Brewster in his "Plurality of Worlds" declares it "equally at variance with reason and Scripture" (p. 171).

We regret that we can continue no further our examination of a work so important in its subject—so thoughtful and so suggestive. To deal fully and fairly with all the issues here opened up would require the study of years. Widely as we differ from the authors, we are bound to pronounce it a book which few men of cultivated minds can read without pleasure and profit. Its main conclusions we are, however, unable to accept. Its arguments, solid and satisfactory at first sight, fade away in our grasp like elfin gold, and leave us empty-handed and disappointed.

V. THE CHANNEL TUNNEL.

By F. C. Danvers, Assoc. Inst. C.E., &c.

It is generally accepted as a geological fact that the high mountains and deep ravines that separate divers nations, and have been adopted by them as natural territorial boundaries, were developed, in some cases by gradual changes in the surface of the globe due to natural causes, whilst in others they are attributed, apparently with good reason, to violent convulsions of Nature, by the action of which the plane of the globe has been caused to undergo great changes. However these inequalities in the earth's surface may have been brought about, the necessities of man often demand that the inconveniences caused by them to free transit should be overcome, and to this end the services of the engineer are called into request—it may be to bridge over a river or chasm, to tunnel through a lofty mountain, under a river or across a channel of the sea. Further also the engineer may be called upon to unite two seas by means of a water communication, to divert the channel of a river, or to guard the coast against the errosive force of tidal action. Taking a general view of the engineering profession, it may be broadly stated that its chief and loftiest operations are undertaken with the view of accommodating the earth's surface to the need of mankind, either by counteracting the physical effects of forces that were in operation in ages past, or by neutralising present active forces by opposing to them means of resistance designed and based upon a knowledge of natural laws and physical science.

Many works of past ages may fairly claim to be classed in the general list given above, of which the most celebrated in modern times, at least, will readily present themselves to the mind of the reader. There is now, however, a grand work in contemplation, for uniting England and France by means of a railway tunnel under the English Channel, which in point of boldness of design and extensiveness—both from a material and commercial point of view—cannot claim a rival.

It is generally admitted by geologists that at one time England was connected with France by land, and formed a Peninsula. To all appearances also the separation from the Continent has not been effected by any violent convulsion, but by the slow and long-continued action of the waves. It was pointed out in an article that appeared in the "Quarterly Journal of Science" for April, 1872, on the "Geology of the Straits of Dover," that, very likely, at one time when the land stood at a higher level, and before the sea had eaten out the Straits, a river ran from South to North through the chalk escarpment, which then stretched across from Folkestone to Wissant. The higher streams of this old river are the Rother on the English side, the Wimereux and the Slack on the French side.

The probability of this country having once been a peninsula, and of the land connecting it with the Continent being washed away by the action of the sea, was carefully considered by Verstigan, so long since as 1673, in a pamphlet dedicated to King James. He compared the identity of the strata, the composition of the cliffs, the similarity of their lengths, and arrived at the opinion that the surface had been gradually worn away by the action of the sea, and not by disruption. In the following century M. Desmarest wrote an essay on the same subject, arriving at the same conclusion; and in 1818 the question was philosophically treated by Richard Phillips, F.R.S., in an elaborate essay which he read before the Geological Society.

Although, however, there appears to be little doubt that the Straits of Dover have thus been formed by the continued action of natural causes, it by no means follows that at no previous period had the even lay of the strata between England and France been disturbed by volcanic or other violent terrestrial forces. Between Folkestone and Cape Gris-Nez there is the Varne in mid-channel of a formation belonging to the Portland beds, which are of a much older series than the deposits to be found on either coast, and this of itself should prepare geologists to anticipate some irregular trend in the direction of the strata between the two shores. It may be that the irregularity is not of sufficient extent at the proposed line of passage materially to affect the projected work, but where an evident upheaval of the lower strata is known to occur within so short a distance of the selected site, it seems but reasonable to suppose that the effects of the disturbance by which it was caused may have influenced the geological formations within a few miles at least on either side of the fault. We shall, however, refer more particularly to this subject when treating of the geological examinations of the Channel bed.

It is not proposed in this article to enter into any detail regarding all the alternative schemes from time to time projected with the view of spanning more conveniently the narrow channel that now separates us from our neighbours, but it may render the present examination of the subject more interesting to refer briefly to the various devices proposed for obviating or lessening the inconveniences felt by those who suffer in crossing between England and France from the too common complaint of *mal de mer*.

From M. Thomé de Gamond's publication on this subject we learn that the establishment of some means of direct communication between England and France was first proposed at the latter end of the last century. The earliest project of which there is any account on record for crossing the Channel by a tunnel was proposed by M. Mathieu, a

French mining engineer, in the service of the Department du Nord. His scheme was conceived at the close of the last century. It was laid before the First Consul in 1802, and plans illustrating the project were for several years exhibited, first at the Luxemburg Palace, then at the School of Mines, and afterwards at the Institute. Mathieu's project consisted of a subterranean way formed of two tunnels, one on the top of the other, forming in section an uneven line, the highest point being in the centre of the Channel, and inclining in opposite directions towards England and France respectively. The lower tunnel was to act as a canal to drain off any waters that might enter through leakage, and from which it would discharge at either end into drainage reservoirs. In the upper tunnel was formed a paved road, lighted by oil jets, and traversed by a service of diligences drawn by horses, which was the only known method of conveyance in those days. It is not shown exactly how the entrances to these tunnels were to be approached on either side, but they must necessarily have been situated at a great depth below the surface of the ground. For ventilating the tunnel, as well as for use in its construction, M. Mathieu proposed to erect circular iron chimneys rising above the surface of the water, and secured in position by masses of rock deposited at their bases.

When the Peace of Amiens was declared the author of this scheme thought that his project would at once be carried out. It was introduced to the notice of Fox on the occasion of his visit to Paris during the short peace that followed, and was received by him with favour: he regarded it as a most efficacious means of assuring peace between England and France. It is stated that Fox spoke on the subject to Napoleon, who exclaimed "Oh! c'est une des grandes choses que nous pourrous faire ensemble."

Subsequently one Dr. Payerne proposed to form a level bed at the bottom of the sea by depositing concrete, and upon this to construct a tunnel by means of diving bells. MM. Franchot and Tessier proposed to form a passage through a tube of cast-iron laid on the bed of the sea, but they appear to have suggested no means for securing a level surface. M. Favre designed a submarine tunnel having an outside casing of wood or sheet iron, and resting on piers of iron lined with brickwork in order to overcome the unevenness of the sea bed. In 1850 M. Ernest Mayer proposed a submarine tunnel between the South Foreland and Cape Gris-Nez, and some years ago M. S. Dunn laid out a plan for constructing a tunnel under the water, of which the principal novelty consisted in a cylindrical protector, fitted with a shield in front, within which the sections of the tunnel were to be fitted together.

The most indefatigable projectors amongst our neighbours has, however, been M. Thomé de Gamond. Whilst making a geological examination of the shores of the Channel in 1833, this engineer was first struck with the idea of making a way of communication between England and the Continent, and he accordingly proceeded to make a series of soundings between Calais and Dover. M. de Gamond's first project was for the submersion of an iron tube in sections, laid at the bottom of the Straits of Dover, and lined inside with masonry. The obstacle which soon presented itself to his mind was the difficulty of levelling the bottom of the sea in order to form a bed for the tube, and this operation alone he estimated at £12,000,000 sterling, after which the cost of the tube and approaches was set down at £6,400,000; so that the total probable cost of the project was £18,400,000. This scheme was no sooner finished than it was abandoned. In 1836, M. de Gamond gave his consideration to the construction of a bridge across the Channel, taking the line from Calais to Ness Corner Point, a line shorter by about two miles and a half than that between Dover and Calais. Five different plans of bridges, in granite, in stone and metal combined, and skeleton iron structures, were elaborated by him during a period of two years. The scaffolds for commencing the works were to be supported by buoys of great size, held in their place by metallic shrouds, fixed at the bottom of the sea to strong moorings. In making the foundations for the piers, it was proposed to drive piles into the ground by manual labour, the workmen being in a water-tight chamber at the bottom of the sea. Of all the different projects for this structure, the one for a granite bridge obtained most favour amongst scientific men. This structure was designed to be 131 yards broad, the arches, 162 yards wide, were to be built on piers 52 yards long and 131 yards broad. All the arches being 57 yards high above the sea could be passed under by most vessels. There was, however, to be one movable arch to admit the passage of vessels having still loftier masts. The greatest depth of sea between these points is stated to be 197 feet, and many of the arches crossing this depth would have been 126 yards in height from the sea-bed to the key-stone. The total cost of this structure was estimated by its designer at 160 millions sterling, but by others at 200 millions. At the advice of Messrs.

Stephenson, Brunel, and Locke, to whom all the plans were submitted in detail, this project was soon abandoned; and in conversations which M. de Gamond had on the subject with those engineers—and especially with Mr. J. Locke—an idea was suggested of improving the means of communication between the two countries by narrowing the Straits of Dover by throwing out piers from the two opposite shores, to be carried as far out to sea as possible, and establishing a steam communication between the two piers by means of an enormous raft moved by steam.

We defer for the present from entering further into detail regarding M. Thomé de Gamond's more matured schemes for a Channel tunnel whilst we refer briefly to other projects that have from time to time been put forward with the view of facilitating the Channel passage between England and France. Taking these in the order of their importance, we may perhaps devote a few lines first in considering plans that have from time to time been proposed with a view to counteract the motion of vessels in a rough sea, and so add to the convenience of travellers. The oldest invention of this sort of which we have been able to trace any record is mentioned in a curious old book, published in 1677, and named "Aero-Chanilos, or a Register for the Air." In it a sort of chamber is described, in which air might be rarefied or condensed, or otherwise changed for the use of invalids, so that they might have change of air without leaving home. Of this same chamber the writer says:—"Possibly, if the same might be made use of on board ship, it would (with the additional contrivance of a chair or bed, hung after the manner of a sea-compass) prevent that very troublesome affection whereto 'fresh men' are subject, called sea-sickness, and consequently become very serviceable to such whose emploiments engage them to undertake voyages into very remote parts, and there to reside far from their own countries."

The earliest patent on the subject appears to be that of Pratt (1826), in which a spring mattrass was fixed on a "swinging frame." A later invention by De Manara, in 1853, proposed to attach balloons to seats, in such a way as to keep them always horizontal. Another, by Ritchie, in 1866, describes a platform, resting on water in a tank, and having its edges attached to the edges of the tank by mackintosh, or similar fabric. Differing from all the above was a plan, patented in 1866, by M. Simpson, in which the body of the patient is firmly fastened down to the ship itself. In 1854, L. Wertheimher patented some improvements in apparatus for preventing sea-thickness, the first of which consists of a movable platform, to which chairs or couches may be attached. Connected with the platform is the piston rod of a steam cylinder, to which steam is admitted by a four-way cock, which may be opened and shut by a self-acting contrivance, so that when the ship sinks into the trough of the sea, steam is admitted beneath the piston, and the platform is caused to rise; on the contrary, when the vessel rises over the crest of the wave, steam is admitted above the piston, and the platform descends, and thus a motion opposite to that of the vessel is obtained. Another arrangement consists of three cylinders, one placed forward and two at the after part, connected with each other by pipes. The second part of the invention consists of a platform or chair, which is supported by a bracket attached to an upright shaft, which shaft passes through a hollow standard. The upper part of the shaft carries a rack in which gears a pinion, fitted with a handle, and a rising and falling motion is given to the platform by moving the handle to and fro. Or the platform may be moved by a perpendicular shaft or lever attached to a pinion gearing with a toothed rack. In the third modification, the effect is attained by interposing elastic bodies between the person and the deck.

In order to avoid sea-sickness, Mr. J. Scarth, in 1869, designed a swinging cot, which he hung from four hooks—two at each end—whilst, in order to counteract the tendency to extreme oscillation, he attached vulcanised india-rubber springs, or accumulators, below the cot, in the exact centre, directly perpendicular from the hooks by which it was hung, and this principle he proposed to apply to individual berths. In 1833, Sir J. Herschel designed a somewhat similar contrivance, which, he says, proved perfectly successful, one chief difference between his and Mr. Scarth's plan being that instead of india-rubber bands Sir John employed cord or pack-thread. Subsequently, in 1869, Sir John Herschel proposed, for swinging cots, to transfer the whole coercing power, operative in deadening the effects of oscillation, at once to the point of suspension; and so doing away with the necessity of attachment of any kind to the walls or floor of the cabin, whether by friction bands or by elastic straps, and this he proposed to accomplish by hanging the cot from the roof by a light but rigid iron framework, having a stiff ball-and-socket attachment lined with compressed felt or other similar material, in order to offer sufficient frictional resistance to oscillation.

A floating cabin was designed by M. Alexandrovski, which, instead of being attached to a pivot, as in the Bessemer saloon, floated in a kind of tank placed amidships between the engines. This invention, it is said, was tested by the Grand Duke Constantine, in his capacity as head of the Naval Department, with a perfectly satisfactory result. All efforts to shake the cabin proving utterly unsuccessful, the pitching as well as the rolling motion of the vessel being completely counteracted. A combination of both the Bessemer and Alexandrovski plans was also recently proposed by Mr. A. Allen, of Scarborough, the object of which was to give a steady saloon cabin or gun deck at sea. This cabin was to be constructed of two spherical segments, the outer segment or dock being fixed in the ship, and the inner segment being floated on a film of water in the dock, like one basin floated in another, the inner one or cabin being maintained at its proper height by being supported on a centre pillar passing up a conical passage in its centre, and which would allow 20 degrees of roll on either side, or 40 degrees in all.

We have now to consider the several plans proposed for conveying trains across the Channel by huge ferry steamers. In the Exhibition of 1862, a proposition by Mr. Evan Leigh for conveying trains across the Straits of Dover on board large ferry boats or rafts was exhibited by means of models, but it does not appear that his project ever found any substantial supporters.

In 1865 a company was formed to place on the Channel a line of steamers from Dover to Calais, so large that the railway trains should run on board them, and there bodily remain to be run out again on the other side after crossing the Channel, and which, by their magnitude, it was expected, would ride over the waves without putting the passengers to the slightest inconvenience. The miseries hitherto inevitable to this passage had, it was remarked, been chiefly entailed by the restriction to boats of a size proportioned to the shallowness of the water on either shore. The new pier at Dover has overcome that objection on this side, and it was rumoured that the French Government had granted a concession for the requisite extension of that at Calais on the other side. Such a scheme was indeed before Parliament in 1866, and was originated by Mr. J. Fowler, whose proposal was to construct steamers one-third longer than the vessels on the Kingstown and Holyhead service, and their decks were to be roofed over so as to protect the trains during the passage. The proposed dimensions of these vessels was—Length, 450 feet; breadth, 57 feet; with 12 feet draught of water. A Bill for effecting improved communication across the Channel by this means was three times before Parliament. In 1869 a project, having the support of Messrs. Fowler, Abernethy, and W. Wilson, contemplated the construction of very extensive harbour and dock works on either side of the Channel in addition to the construction of the large ferry steamers above referred to, and in November of that year an influential deputation from England laid the scheme before M. Gressier, the Minister of Public Works in France, by whom it was favourably entertained.

In consequence of the very defective state of the accommodation afforded by the Channel steamers plying between this country and the Continent, the Council of the Society of Arts, in 1869, offered the Gold Medal of the Society and the large Silver Medal of the Society for the best and the second best model of a steamer which should afford the most convenient shelter and accommodation to passengers on the deck of the vessel crossing the Channel between England and France. The size of the vessel was not to exceed in tonnage and draught the best vessels then in use between Folkestone and Boulogne. Seventeen models were sent in competition, which were referred to a Committee consisting of Lord Henry G. Lennox, M.P., Seymour Teulon, Rear-Admiral Ommanney, C.B., F.R.S., Admiral Ryder, E. J. Reed, C.B., Capt. Boxer, R.N., C. W. Merrifield, F.R.S., H. Cole, C.B., and Captain Tyler. From the report of this Committee it appears that three of the models only conformed to the conditions laid down by the Council, but none of these, in the opinion of the Committee, presented sufficient novelty or merit to justify the award of the medal.

In this year also Captain Tyler, R.E., in compliance with instructions from the Board of Trade, visited the French and English coasts with a view to preliminary enquiry as to the improvements which might be effected in the means of communication between the two countries. He reported that considering the restrictions as to dimensions imposed by the circumstances of the harbours and the various conditions of the service, the steamers employed in the Channel service were admirably constructed for the work they were required to perform. With regard to Mr. Fowler's proposal for large steamers and improved harbour accommodation on both sides of the Channel, Captain Tyler observed that it was a question whether it would be worth while to ferry the railway carriages as well as the passengers across the

Channel; but that the main features of an improved harbour at Dover and a new harbour south of Cape Gris-Nez were sound, if means could be found for meeting so great an expense as the works would entail. Captain Tyler then proceeded to consider the practicability of improving the existing harbours so as to fit them for a service of larger vessels, after which he directed attention to the bolder schemes which had been put forward from time to time for avoiding the use of steam vessels altogether by the construction of bridges, or tunnels, or tubes over, under, or in the bed of the Channel, with or without islands, piers, or air-shafts, so as to connect the railway system of England directly with that of the Continent.

After briefly referring to the plan proposed by M. Mathieu, Captain Tyler proceeded to observe that, after a series of geological investigations, M. Thomé de Gamond also proposed, in 1856, the construction of a tunnel, and his propositions were submitted to the examination of a scientific Committee by order of the French Emperor in that year. That commission appears to have come to the conclusion that it was desirable to test his investigations by sinking shafts and driving short headings under the sea at the expense of the two Governments. Mr. Low, an English engineer, also laid his plans for a tunnel before the Emperor in 1867, and Mr. Hawkshaw, whose attention had been for some years directed to the subject, caused a trial boring to be sunk on each side of the Channel in 1866 in order to test practically the result of his geological investigations. Mr. Remington published a plan for a tunnel in 1865, and deposited plans and sections of it with the Board of Trade. And amongst the names of other proposers or projectors in this direction may be enumerated Messrs. Franchot, Tessier, Favre, Mayer, Dunn, Austin, Sankey, Boutet, Hawkins Simpson, Boyd, and Chalmers. Of these various projects those which have of late made the most progress are the bridge scheme of M. Boutet, and the tunnel scheme presented under the chairmanship of Lord Richard Grosvenor, with Messrs. Hawkshaw, Brunlees, and Low as engineers on the English side, assisted by Messrs. Talabot, Michel Chevalier, and Thomé de Gamond on the French side. The result of the deliberations of a French commission, which was appointed by the Emperor, and presided over by M. Combes, the Director General of the Ecole des Mines, to inquire into this last-mentioned scheme, were on the whole favourable as regards the geological and engineering parts of the project, though the members of the commission were divided as regards its financial prospects, the president and two members attaching more importance to the "utility and grandeur of the undertaking," and three other members looking at it from a more strictly economical point of view. The General Council of Pont-et-Chaussées, presided over by the Minister of Public Works, to whom the matter was afterwards referred, were unable, "upon the documents submitted to them, to decide on the probability of success of the tunnel under the Channel," and considered that "if from political considerations, the undertaking should be considered useful, the Government should follow up the investigations at their own expense."

In reporting on the different projects put forward with a view to improving the means of communication between England and France, Captain Tyler, referring to the last mentioned project, remarked :—

"In this scheme it is proposed to commence by driving preliminary driftways through the grey chalk, at a great depth below the bed of the Channel, between a point near Dover and another point near Calais; as it is conceived that this material would be easily cut through, and would not be likely to present insuperable difficulties from the influx of water; whereas Mr. Remington selects the line from Dungeness to Cape Gris-Nez, in order to avoid the chalk, and the fissures which he fears to encounter in it, and to work in the Wealden formation, which would, he believes, afford a greater chance of success.

"In the case of M. Boutet's bridge scheme, an association has been formed for making experiments, two small bridges have been built in France, and arrangements are made near St. Malo for a third, a mile in length, to be constructed in two spans of half a mile each. The Emperor Napoleon visited the works of M. Boutet, on a site granted by the French Government, and His Majesty is stated to have expressed himself favourably with regard to the project. This bridge is intended to cross from Dover to Blancnez, and is advocated, in a paper forwarded on the 27th June to the Board of Trade as (1) being less costly than a tunnel; (2) occupying less time in construction ; (3) giving no trouble in ventilation ; (4) avoiding the danger of sudden inundations.

"Mr. Charles Boyd has forwarded to the Board of Trade a pamphlet containing his proposal for a 'marine viaduct' from Dover to Cape Gris-Nez, constructed with iron girders on 190 towers, 500 feet apart, and 500 feet above the sea, and he estimates the cost of such a bridge at £30,000,000.

"Mr. Hawkins Simpson has addressed the Board of

Trade on the subject of working a submarine tunnel on a pneumatic system, which he has termed his 'Eolian system,' for which he claims cheapness, expedition, superior ventilation, and greater utility.

"Mr. Alexander Vacherot has submitted to the Board of Trade a scheme on which he has several years been engaged, and which he laid before the Emperor of the French in 1856, for 'laying on the bed of the sea a tunnel made or formed of concrete, so as to form, when completed, a monolith.' He would construct it on the shore and 'draw it down to its place in sections.' And he considers that greater economy and security might thus be obtained than by the other methods that have been proposed."

After reviewing these several projects Captain Tyler, though unable to convince himself of the feasibility of any bridge scheme, considered "that it might be wise to test the practicability of a tunnel scheme by means of preliminary driftways. It is probable," he said, "that, even if any of them should hereafter be carried out in practice, they could not go forward otherwise than under the supervision of, and a previous guarantee from, the two Governments; and obvious that, as at least 10 or perhaps 15 years may elapse before they could be made available for traffic, improvements in the shape of more convenient and larger steam vessels are required in the meantime for the better performance of the service."

In the spring of 1870 Vice-Admiral Sir Edward Belcher read a paper before the Institution of Naval Architects wherein he expressed himself favourable to a proposed ferry scheme, and to the practicability of constructing ferry steamers suitable for the service. The outbreak of war on the Continent put an end to Mr. Fowler's project; but, in 1871, we find M. Dupuy de Lôme at the head of a similar undertaking in France. His project was for, first, the creation at Calais of a maritime station, with 16 feet 6 inches depth of water at the lowest tides, and about 30 acres in area, connected with the shore by an iron railway jetty, making a junction with a branch of the Northern Railway—and open to the sea by an entrance 260 feet wide, accessible in all weathers, and at every stage of the tide; secondly, the construction, for crossing the Channel, of steam vessels of large dimensions and of great power, embracing all of the most important conditions of speed and comfort, and able to carry 30 passenger carriages or goods wagons. These vehicles would be placed on a double line of rails running fore and aft; they would be shipped and unshipped by the assistance of a system of inclined planes leading to three landing stages of different heights, and alongside which the ferries would run according to the state of the tide. A paper on this subject was read by M. Dupuy de Lôme before the French Geographical Society in 1873. In 1871 the Society of Arts appointed a Committee to consider and report how far the existing means of crossing the Channel could be improved. In their report several modifications in existing vessels, and new boats about fifty feet longer than the existing boats, were suggested, but an opinion was expressed that no large measure of improvement could be effected in the Channel passage unless with vessels of much larger size, which would involve, in the first instance, considerable improvements in the French harbours of Calais and Boulogne, and subsequently the extension of the low-water pier at Folkestone.

Mr. Fowler again brought forward his ferry scheme in 1872, and Mr. Hawkshaw at the same time was supporting an alternative design for an improvement of the existing means of communication by the establishment of a service of vessels of considerable size, to which the existing harbours might be adapted without an excessive cost.

The Bill for Mr. Fowler's project passed the House of Commons in 1872, but it was thrown out in the Lords by a very small majority. From this date comprehensive schemes for a railway ferry across the Channel appear to have been abandoned, and in their place projects were started, the one by Mr. Dicey and the other by Mr. Bessemer, for constructing steamers of special and novel design, on board of which passengers would be enabled to undertake the passage across the Channel without fear, no matter how bad sailors they might be. Both of these vessels have now been constructed, and as they have been described in former pages of this journal it is not necessary to enter into any detailed description of them on the present occasion.

Having now made a rapid review of the general question of improved communication between England and Europe, and of the several projects that have from time to time been proposed for the purpose, it remains only to enter somewhat more fully into detail with regard to the great tunnel scheme which, to all present appearances, is about to be commenced. In doing this we shall purposely avoid all reference to the probable traffic and commercial results of the undertaking, and shall confine our investigations to the proposed line of route, the geological features of the strata to be pierced, and the general engineering features of the work.

Two principal schemes have been proposed for a tunnel under the Channel, the one by M. Thomé de Gamond between Eastwear Bay near Folkestone, on the English side, to Cape Gris-Nez on the French coast, and the other, which has already been referred to, and with which the names of Hawkshaw, Brunlees, and Low are associated, from between St. Margaret's Bay, near the South Foreland, to a point between Sangatte and Calais. The former of these, it was subsequently ascertained, would pass through a number of different beds. In mid-channel on this line there are two shoals, known as the Varne and the Ridge, which belong to the Portland formation, the same as that to which the cliffs at Cape Gris-Nez belongs, and under it are the Kimmeridge Beds. These rocks dip to the north-west, and it is supposed that somewhere between Cape Gris-Nez and the Varne the Kimmeridge clay wholly disappears, whilst somewhere to the west of the Varne and nearer to the English coast the Portland beds also disappear and are overlaid by the Wealden series. Probably the Hastings beds immediately overlie these, and above them again is the Weald clay; but where the outcrop occurs, or what is the thickness of the various beds, is not known. M. de Gamond's tunnel, therefore, as was pointed out by Mr. William Topley in an article on the "Geology of the Straits of Dover," which appeared in this Journal in April, 1872, would pass through a number of different beds; but how many is uncertain, for it crosses the lines along which the changes above indicated must somewhere occur. There is no doubt that it would pass through all the English divisions of the Lower Greensand, for it would intersect these very near the coast; and it cannot be supposed that the change which these must undergo takes place suddenly. Farther out in the Channel it would probably go through Weald clay, possibly it might touch the Hastings beds; beyond this again it might intersect the Portland, and finally it would cut through the Kimmeridge. The various beds that would be intersected by this tunnel are of very different characters; some are highly porous and some wholly impervious.

The tunnel which it is proposed to take from St. Margaret's Bay to near Sangatte will, it is supposed, go entirely through the chalk without flints. The following particulars of this project are taken from a paper on the "Channel Tunnel" read before the Society of Arts on the 18th March, 1874, by Mr. W. Hawes, F.G.S., and from a "Statement by the Committee of the Channel Tunnel Company (Limited)" published in 1874.

In 1865 Sir John Hawkshaw began his practical researches into the nature of the strata beneath the Channel, which confirmed the theories of the geologists, threw new light on the subject, and put the question of a submarine tunnel in a position to be seriously discussed and considered by the public. Before that time he had given the subject much consideration, but in that year he caused careful geological surveys and investigations to be made of the Channel, and afterwards, in conjunction with the late Mr. Brassey and Mr. George Wythes, had borings sunk on each coast. Subsequently, by means of apparatus contrived for the purpose, he examined the bottom of the Channel all across in a great number of places, and raised specimens of the sea bed for examination, by which it appears to have been satisfactorily established that the actual position of the chalk across the Channel is very nearly identical with that deduced from previous enquiries, and its unbroken continuity placed almost beyond doubt. Its thickness, determined by deep borings on both sides, is proved to be above 500 feet below high-water mark, with an ample thickness of the lower or grey chalk between the bottom of the sea—which is nowhere more than 180 feet deep—and the crown of the tunnel, as well as between the bottom of the tunnel and the green sand or water-bearing strata underlying the grey chalk. The tunnel has been placed by the engineers at such a level that the depth of strata over it will nowhere be less than 200 feet, and this depth, which is desirable for security, will permit the railway approaches to be formed with not unfavourable gradients.

In the opinion of M. de Souch, Inspector-General of Mines in France, the line selected by the engineers of the Channel Tunnel Company is the only one which presents chances of success, and is the only rational one. The Commission appointed by the late Emperor of the French to examine this project reported that there was every reason to believe that the chalk formation extends under the Channel between Dover and Calais and that "the thickness of the grey chalk gives a certain latitude for the maintenance of the tunnel in the same direction, even where the level of the bed of the sea may be subject to some undulations; and they believe that the existence of any great fracture in the chalk is very improbable."

On the other hand, we have the opinion of so high an authority as Mr. Joseph Prestwich, Vice-President of the Geological Society, who does not entertain such sanguine views as to the suitability of the chalk stratum for the construction of the proposed tunnel, as will be seen from the following remarks extracted from a paper read by him before the Institution of Civil Engineers in December, 1873:—

"The chalk formation, which everywhere in the south-east of England and the north-west of France underlies the Tertiary series, has a maximum thickness of from 1000 feet to 1300 feet; but, as much of it has in this area been worn away or denuded before the deposition of the Tertiary strata, its actual thickness in the district under notice varies from 300 or 400 feet to 800 or 1000 feet. The upper beds consist of almost pure carbonate of lime, easily worn by water, and being also soft and fissured they are readily permeable. But the Lower Chalk or Chalk Marl contains so large a proportion of argillaceous matter and silica in a state of fine division that some beds pass almost into a clay, and when unbroken and compact very little water can pass through them, and then only with extreme slowness, though this will increase under pressure. But although a small bore-hole or even a shaft may often be carried through a considerable thickness of Lower Chalk and no water obtained, the occurrence of fissures is too uncertain to render it a reliable medium over a large area. In some cases where the Lower Chalk comes to the surface, and is more broken and fissured, the quantity of water it yields is very large, as in the instance of the Tring cutting described by Robert Stephenson, where the discharge was at the rate of 1,000,000 gallons per day; or at Folkestone, where the town water supply is obtained from the Lower Chalk of the adjacent downs. On the other hand, the Chalk Marl in France and Belgium acts as an impermeable stratum in stopping the passage of water from the very permeable Upper Chalk into the underlying coal measures; and no water was found in it either at Kentish Town, Harwich, Southampton, or Calais; but the diameter of the bore-holes by which they were traversed were very small. At Calais one spring was met with at a depth of 70 feet in the Upper Chalk, and the water was brackish, showing communication with the sea. Nor must it be forgotten that wells in the Chalk under London have to be carried or bored to depths of from 10 to 300 feet before meeting with water-bearing fissures, or else headings have to be driven in search of one. Again, the escarpment of the North Downs and that of the chalk hills of Wiltshire, Oxfordshire, and Buckinghamshire are fringed with numerous springs, which issue at their base. These springs, although thrown out generally by the Chalk Marl, are apparently not always at the top of it, but often low down in the deposit, and they constantly wear their point of issue from a higher to a lower level. Whatever the level of the spring the water of course passes through all the superincumbent portions of the Chalk Marl. This very commonly impermeable character of the Chalk Marl has given rise to the hope that it might prove compact enough for a submarine tunnel under the Channel between Cape Blancnez and the South Foreland; but when it is considered that such a work would have to face the risks arising from the lateral passage of the inland springs and from the chance fissures so common to calcareous rocks communicating with the sea, it is feared that the difficulties would prove to be of a very formidable nature. It is to be observed that in the Channel the chalk is frequently bare, besides being unprotected by any overlying strata."

The foregoing observations demand our full respect, but, on the other hand, the possibility of tunnelling beneath the sea without being exposed to an irruption of sea water is shown in the submarine galleries of some mines in Cornwall, Cumberland, and elsewhere. In a treatise on Mines and Mining by Mr. Price, published in 1778, he treats especially of mining under the sea, and refers particularly to the freedom of water in such works.

It is probable, and the engineers anticipate that at the shore end of the Channel Tunnel, especially in constructing the shaft through the upper strata, a considerable quantity of water will be met with, but not sufficient to prevent the execution of the work, where pumping power of any magnitude could, if necessary, be applied. It is believed, and there appear to be reasonable grounds for such belief, that as the work attains a greater depth in the chalk, and especially after the lower or grey chalk is reached, the quantity of water will diminish, and that in mid-channel it will be less than at the sides.

The geological features of this project having now been duly considered, it remains to give some particulars of the engineering nature of the work. The distance across the Channel at the point selected is about 22 miles, but as considerable approaches will be necessary on either shore, in order to reach the level of the tunnel entrance, the entire scheme will embrace about 31 miles of railway. In the first instance shafts will be sunk on each shore to the depth of 450 feet below high-water mark, and, from the bottom of these, driftways will be driven for the drainage of the works whilst in progress, and for its permanent drainage after completion. The tunnel, which will be very similar to an ordinary railway tunnel having two lines of rails, will commence 200 feet above this driftway, and will be driven at an inclination of one foot in 80 to the junction with the drainage driftway, and then at a gradient of one to 2640 to the centre of the Straits, where the tunnel from the English shore will meet that driven exactly in the same manner from the French shore, and, being united with it, will complete the submarine railway under the Channel. The drainage will be from the centre of the tunnel to either end.

In the execution of this work a driftway, 9 feet in diameter, will first be carried right through, and this will afterwards be enlarged to the full size of the tunnel. The problem of the execution of the tunnel in a reasonable time has been simplified by the invention of tunnelling machinery, and the machine of Mr. Dickenson Brunton, which has been tried on a practical scale by the company in the lower or grey chalk, has been quite successful. The machine works like an augur boring a hole in wood. The chalk is cut off in slices, which break up and fall upon an endless band, which loads them into wagons behind the machine. The apparatus was tried by the Company at Messrs. Lee's Cement Works, Snodland, near Rochester, in the grey or lower bed of chalk, such as underlies the Channel. It made a driftway of 7 feet diameter, and it advanced at the rate of from a yard to a yard and a quarter per hour. At this rate it would only require two years to drive a driftway of 7 or 9 feet diameter from one side of the Channel to the other, a machine being started from each side. The cost of driving a heading would consist—1st, of tunnelling machines, pumps, and pumping engines; 2nd, the hand labour, which would not be considerable, as the machine requires but few hands to work it; and, 3rd, interest on the capital expended during the execution of the work, which might last two years or more. Taking these three elements of expenditure into consideration, and according to the calculations of experienced contractors, it has been found that the driftway could be executed for £800,000, if it required only two years to make it.

As soon as the driftway was completed the success of the undertaking would be assured. It would furnish the necessary data for an exact estimation of the cost of the whole work and the time necessary for its execution. In fact, all that would be necessary would be to enlarge the driftway to the dimensions of an ordinary railway tunnel. It has been estimated by some engineers and contractors of considerable experience that after the driftway was finished, four years' time and four millions of money would complete the work, including the junctions with the English and French railways on either shore. Sir John Hawkshaw and the engineers associated with him, however, think it prudent to double this estimate both of time and of cost, at least until the preliminary work shall have given them the necessary data for a more exact estimate of the duration and cost of the work.

Preliminary steps to test the practicability of the project are about to be put in hand without further delay, for which purpose an English and a French Company have been promoted to carry out experimental works on either side of the Channel. An Act has been passed by the British Parliament during the past Session to enable the English Company to acquire the necessary lands at St. Margaret's Bay, and it is understood that a *projet du loi* has also been passed in the French Senate to confer the necessary powers on the French Company. The works to be undertaken by these companies consist of sinking two shafts—one on either coast—about 150 yards deep, from which an ordinary mining drifting about half a mile long will be driven under the sea. This work would be a true beginning of the proposed permanent tunnel. Its cost is estimated at £160,000, of which sum it is understood the two companies will find £20,000 each; the Rothschilds of London and Paris have each undertaken to find similar amounts; the Chemin de Fer du Nord will contribute £40,000, and the London, Chatham, and Dover and South-Eastern Railways will respectively subscribe £20,000.

It may now be confidently anticipated that the commencement of this great work will not be delayed. In the foregoing account we have purposely refrained from entering into detail regarding means of ventilation and other minutiæ of construction. The progress of the work will, however, be closely watched, and we shall hope from time to time to give further particulars of its advancement in the chronicles of engineering in this journal.

VI. THE ARCTIC EXPEDITION OF 1875.

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AT frequent intervals during the last 300 years, the Arctic Circle has been crossed, and portions of the vast space within it have been explored. Foremost among the nations which have prosecuted such researches are the English, Russians, and Dutch, while the Americans, Austrians, and Norwegians have latterly done good work in the same fruitful field. Within that charmed circle of eternal snow and ice the difficulties to be encountered are prodigious, and the attractiveness of the exploration cannot compare with that of tropical or temperate portions of the earth's surface. "A region of thick-ribbed ice, the home of the walrus, seal, and bear, uninhabited by man; a stranger almost to flower and tree, whose forest giant is the dwarf birch, a tree 13 inches in height; the resting-place of iceberg and floe; the seat of land which is wrapped in a mantle of frozen water, and of seas whose solidity equals that of the rocks; a spot on which for four months the sun never shines, where the cold freezes the mercury, and the thermometer in March ranges 70° below zero." Such is this inhospitable region which it is the design of the Arctic Expedition of 1875 to open up to the further knowledge of mankind.

The causes which have induced enterprising maritime nations to risk the lives of their bravest men, and to expend vast sums of money, in endeavours to penetrate an unknown region, have been very various. In the case of most of the earlier and many of the later expeditions, the principal cause was commercial interest rather than discovery for discovery's sake. Hence Milton was led to remark that the early attempts at Arctic exploration "might have seemed almost heroic, if any higher end than love of excessive gain and traffic had animated the design." The various causes which have induced Polar research are the following:—(1). The search for a north-west passage from the Atlantic to the Pacific, in view of closer commercial relations with India and China. (2). The search for a north-east passage to the Pacific, in view of closer commercial relations with the north of Russia, Siberia, China, and India. (3). The search for fresh whaling grounds. (4). The search for gold mines. (5). The exploration of the Hudson's Bay Territory and of Northern Siberia, for the furtherance of commerce. (6). The search for the lost *Erebus* and *Terror*. (7). Rewards offered by governments or individuals. (Thus a century ago a reward of £20,000 was offered by Parliament for the discovery of the north-west passage; also a reward was offered for the first man who should sail beyond the 89° N. lat; and in 1818 Parliament offered £1000 to the first man who should sail beyond 83° N. lat., £2000 if he sailed to 85°, £3000 to 87°, £4000 to 88°, and £5000 to 89°; again £10,000 was offered for the solution of the mystery which so long overhung the fate of *Erebus* and *Terror*). (8). The prosecution of scientific research, including geographical surveys and deap-sea soundings. (9). In the case of our expedition of 1875, the acquirement of "important scientific and commercial results" . . . "the importance of encouraging that spirit of maritime enterprise which has ever distinguished the English people," . . . "the discovery of the conditions of land and sea within the unknown area, and the investigation of all the phenomena in that region in the various branches of science." (10). The discovery of the North Pole.

We have put last on our list, and would fain have omitted altogether, that which many will regard as the primary object of Arctic research; but in truth the expression "discovery of the North Pole" is scarcely more than a phrase. The North Pole is in some respects of less interest than the magnetic pole discovered more than 40 years ago. The North Pole of the earth is merely a point terminating the axis of rotation of the earth. It is a spot on the earth's surface where the altitude of the sun is equal to its declination; where the sun seems to revolve in a circle parallel with the horizon, and not to rise on one side of the horizon and set on the other, as with us. Nevertheless, if we like to make the discovery of this spot on the earth's surface, our goal in the Arctic race, well and good; the phrase may be retained, because we well know that the pole cannot be reached without a considerable exploration of the land lying around it, and this is the real present object of Arctic research. It is a useful phrase because you cannot explain to the nation in general, and to the sailors of the expedition in particular, the results geographical, magnetical, electrical, thermal, hydrographical, geodetical, meteorological, geological, botanical, zoological, and ethnological, which may be expected to accrue from the observations of the expedition; while the phrase "discovery of the North Pole" has in it a stimulating ring, a something tangible and real—albeit it conveys less meaning to nine people out of ten than if we spoke of the discovery of the Fountain of Jouvance, or the Garden of the Hesperides. To our enterprising spirits there is in the term something which excites and stimulates: the discovery of a spot of earth upon which man has never trod, the attainment of a goal for which many have started, and which none have ever reached; a something that shall call forth all the heroism, energy, and endurance of which a great nation is capable. Let us look back at our list of objects sought to be accomplished by Arctic expeditions, and see how many now remain to us. (1). The North-West Passage was probably discovered by the survivors of the *Erebus* and *Terror*, and was certainly discovered a few years later (1851) by Sir Robert McClure, who found a strait connecting Melville Sound with the Continental Channel, and who was thus enabled to sail from the Atlantic to the Pacific. (2). The North-East Passage has been proved to be altogether unpractical, if not altogether impossible. (3). The highest practicable whaling grounds have been discovered. (4). The gold mines have been proved to be fabulous, and the imagined gold ore to be iron pyrites. (5). The Hudson's Bay Territory and Northern Siberia have been fully explored. (6). The numerous expeditions sent out between 1847 and 1857 to search for the crews of the *Erebus* and the *Terror* have done their work. For a while their search ended as did the search of the sons of the Prophets for Elijah who had been taken from their sight; afterwards they found the records of the lives of brave men, the graves of heroes. (7). Of the rewards offered by Parliament, some have been won, others remain as yet unclaimed. (8). The prosecution of scientific research remains with as wide a field as ever, although much has been done. (9). The results of our present expedition, which we trust we may be able to give in October, 1876, and among them let us hope (10) the discovery of the North Pole. We suppose that a recent writer in the "Times," when he speaks of solving the "Polar mystery," means finding out whether the North Pole is surrounded by a great open sea, or whether it is situated on land; but Polar research, as we have shown above, means much more than the discovery of this spot on the earth's surface. In fact this is of less than secondary importance among the results of our expedition. As a means to an end it is alone important, for this one spot of earth cannot be discovered without the pre-discovery of ten thousand scientific facts.

Before we enter into an account of some of the more notable attempts to explore the Arctic Regions, let us open a map and glance at the region in question. Looking down upon the North Pole of the earth, we notice at a distance of about 1500 miles from it (about as far as from the North of Scotland to the South of Spain), the circumference of the Arctic Circle. Travelling east from Iceland, we observe that the latter just touches the northern border of that island, passes through the north of Norway, Lapland, and Russia, the south of the Gulf of Obi and Northern Siberia, passing a few miles to the north of the narrowest portion of Behring's Straits; continuing through Alaska, it cuts the northern portion of the Great Bear Lake and Cumberland Sound, the middle of Davis Straits, and so through the south of Greenland to Iceland again. Grouped around the Pole at distances of from a thousand to twelve hundred miles, we have the great northern limits of Europe, Asia, and America. The great space of more than one and a half million square miles marked "unexplored Polar Region" is entered from the Atlantic and Pacific Oceans by three channels—to wit, from the Pacific Behring's Straits, from the Atlantic, Davis Straits, and the great stretch of ocean extending between Greenland and Norway. If we finally narrow our gaze to the innermost circle, 10° (690 miles) from the Pole we notice that through more than half that circle no land penetrates; indeed it is an altogether unknown region. Above the north-west corner of Greenland, we have President's Land within 400 miles of the Pole, while above Novaya Zemblya we have Petermann Land, also within 400 miles of the Pole.

Iceland, the northern portion of which, as we have seen, is on the edge of the Arctic Circle, was discovered in the year 860 A.D., by a Norwegian Vikingr, and fourteen years later it was colonised by Norsemen. About the year 890, Audher, a Norwegian, gave an account of his voyages to Alfred the Great, and there can be no doubt from his story that he was the first to double the North Cape and to enter the Arctic Circle. Nearly a century later Erikr Rauthi, an Icelander, having been convicted of manslaughter, was banished from the country, and determining to pass a portion of his time of banishment in exploring the Northern Seas he fitted out a vessel and soon came in sight of the east coast of Greenland. He then doubled Cape Farewell, and landed on the western coast of Greenland, which he spent three years in exploring. In 986 he returned to Iceland and reported so favourably of the new-found country that he persuaded a large body of his countrymen to sail with him, and a colony was forthwith founded. The colony was divided into East and West Bygd (Ice., *byggia*, to build): the former ultimately contained 90 farms and 4 churches, and the latter 190 farms, a cathedral, and 11 churches. The colony was christianised towards the close of the tenth century, and sent tribute to Rome in the form of the tusks of the morse. Early in the fifteenth century the colony ceased to exist. It had undergone various misfortunes: a plague had broken out among the inhabitants; an irruption of the aborigines (Esquimaux) had disturbed the settlement; and finally a hostile fleet laid waste the country. During the occupation of Southern Greenland by the Icelanders America was discovered.

In 1492 Columbus discovered the West Indies, and in 1498 Vasco di Gama doubled the "Cape of Storms." The English merchants were cut out from any share of the commerce of the Indies, for the Pope had assigned the eastern route to the Portuguese, and the western to the Spaniards; hence it was that the Merchant Venturers of Bristol determined if possible to achieve a *North-West Passage* to the Pacific. In the reign of Edward IV. a Venetian merchant named Giovanni Gabotto had settled in Bristol, and according to Hakluyt his celebrated son Sebastian was born in that city in 1467. Letters patent were presented to John Gabot and his sons by Henry VII. permitting them to sail under the English flag, and to set up the flag in every newly discovered land. In 1497 John Gabot discovered Labrador and Newfoundland. He appears to have made two voyages in search of a north-west passage, and to have penetrated to the 58th degree of latitude. This was the first attempt of the English to make the North-West Passage. In 1527 one Robert Thorne presented an address to Henry VIII. praying that ships might be sent out to the North in quest of new lands, since other nations had already made important discoveries in the direction of South, and West, and East. He argued that if the seas above Newfoundland be navigable it would be possible to sail due North, pass the Pole, and descend to the equinoctial line near to the Spice Islands, and thus to outstrip the Spaniards and Portuguese. Two ships were equipped for this purpose by Henry VIII.; one was lost in a storm, the other got no further than Newfoundland.

An attempt was made in the reign of Edward VI. to sail to India by a north-east passage, and a company of merchants (afterwards incorporated and styled "The Fellowship of English Merchants for the Discovery of New Trades," but now commonly known as the "Muscovy

Company), sent out three vessels sailing under the directions of Sebastian Cabot, Grand Pilot of England. The crews of two of these vessels, together with the Admiral, Sir Hugh Willoughby, were frozen to death near the mouth of the Northern Dwina. The crew of the third vessel returned overland to England from St. Nicholas on the White Sea. The Muscovy Company, nothing daunted, fitted out a pinnace named the *Serchthrift* in 1556 for the search for the North-East Passage. Sebastian Cabot, although in his 88th year, was an active member of the company, and directed the new expedition, the command of which was given to Stephen Borough. "On the 27th of April," says Borough, "being Monday, the Right Worshipful Sebastian Cabot came on boord our pinnesse at Grauesende, accompanied with divers gentlemen and gentlewomen, who, after they had viewed our pinnesse and tasted of such cheere as we could make them aboord, they went on shore giving to our mariners right liberall rewards, and the good olde gentleman, Master Cabota, gave to the poore most liberall almes, wishing them to pray for the good fortune and prosperous successe of the *Serchthrift*—our pinnesse. And then at the sign of the Christopher hee and his friends banketed and made mee and them that were in the company great chere; and for very joy that he had to see the forwardness of our intended discovery, he entred into the dance himselfe among the rest of the young and lusty company: which being ended hee and his friends departed most gently, commending us to the governance of Almighty God." During this voyage Borough discovered the Strait between Novaya Zemlya and Vaigat Island sometimes called the Strait of Kara; but he did not prosecute his researches further to the East, having seen "a terrible heape of ice approach neere." The Dutch stimulated by the English attempts to effect a north-east passage sent out an expedition from Amsterdam in 1594 commanded by William Barentzoon, who made three voyages, the third of which was by far the most important. During this voyage he discovered Spitzbergen, and sailed round the north-west end of Novaya Zemlya. In the winter of 1596-97 Barents, with sixteen of his countrymen, found themselves entirely hemmed in by ice at the north of Spitzbergen, and they were compelled to land and build a house out of drift-wood and portions of their ship. In June, 1597, they set sail for the South, and a few days later Barents died. The survivors, after undergoing frightful hardships, reached Kola, in Lapland, after a voyage of 1600 miles in open boats through a stormy and icy sea, and were picked up by a Dutch vessel.

In 1871, no less than 278 years since the crew of Barents wintered in Ice Haven, the old house and numerous relics were found by a Norwegian captain, among them the clock and some books. The interior of the house was exactly in the condition described by Barents nearly three centuries before.

Seventy-six years after Sebastian Cabot's attempt to effect a north-west passage, Sir Martin Frobisher persuaded some London merchants to once more embark in the enterprise, and three small vessels were fitted up for the purpose and victualled for twelve months. They started on the 17th of June, 1576, and passed by Greenwich, "where we shotte off our ordinance and made the best show we could; Her Majestie (Queen Elizabeth) beholding the same, commended it, and bade vs farewell with shaking her hand at vs out of the window. Afterward she sent a gentleman aboord of vs, who declared that Her Majestie had good liking of our doings, and thanked vs for it, and also willed our captaine to come the next day to the Court to take his leave of her." Frobisher speedily doubled Cape Farewell and bore on to the West until he came to land, which Queen Elizabeth named Meta Incognita; a little to the north of this a large bay was found which was named "Frobisher's Bay." When Frobisher returned to England he brought with him not only the hopes of a north-west passage but a piece of black stone, which being examined by Baptiste Agnello, a quack, was found to contain a minute quantity of gold. Whereupon the London merchants again fitted out ships, and Frobisher was ordered to load them with the supposed gold ore, and to defer discovery till some more convenient time. The ships returned and the ore was found to be worthless, and for nine years the London merchants refused to send out a fresh Arctic expedition. In 1585, however, several vessels were fitted up and put under the command of John Davis with a view to the discovery of the North-West Passage. He discovered the straits which bear his name in 1585, and gave the name of Cape Walsingham to a prominent Cape on the East side of Cumberland Island. This is just below the Arctic Circle, and Davis is the first Englishman who reached so high a latitude on the American shore. Cape Chudleigh, the most northerly point of Labrador, was also discovered by Davis and named by him after Mr. John Chudleigh. In 1607 Henry Hudson was entrusted by the Muscovy Company with a small vessel for the discovery of the North-West Passage. There seems to be but little doubt that in the course of this voyage Hudson discovered Jan Mayen's Island, which is generally (but on weak grounds) said to have been discovered five years later by a Dutchman after whom it was named. Hudson also penetrated to a latitude of 80° 23′. In a second voyage Hudson discovered the river which bears his name. Hudson's Bay was discovered in 1609. In 1612 William Baffin and James Hall visited the West Coast of Greenland in order to search for a gold mine which was said to have been worked by the Danes. Twenty four years later the Danes sent out two vessels to the same spot with the same object, but they returned laden with iron pyrites. Baffin discovered the Bay which bears his name in 1616. Mr. Markham points out the curious fact that although the Dutch had established a flourishing whale fishery in Davis's Strait, the passage of the "Middle Pack" (that is the great mass of ice in the middle of Baffin's Bay) was not even attempted between 1616 and 1817. Baffin had himself passed the Middle Pack and reached the extreme north of the bay, but no one had followed in his footsteps, until in 1817 two whalers successfully passed the Middle Pack, and found an abundance of whales in the "North Water." A number of whalers now pass the Middle Pack every year.

We have seen to how great an extent our knowledge of Arctic geography is due to the Muscovy Company: another company had now arisen in the very heart of the Arctic district. A charter was granted in 1670 to the Hudson's Bay Company, giving them right to all the territories drained by rivers falling into Hudson's Bay, on certain specified conditions, one of which was the prosecution of geographical research. Expeditions were frequently sent out by the Company both for surveying the coast line and for the exploration of the interior. In 1741, Captain Middleton, who was a sound scientific man, well versed in nautical astronomy, was appointed by the Admiralty to explore Hudson's Bay. He penetrated to the extreme north, and there found a frozen strait, which seemed to cut off all communication with more northern seas. A few years later the Admiralty offered a reward of £20,000 for the discovery of a north-west passage, but the attempt, although often made, was fruitless.

In the other direction the Russians had often attempted a survey of the Siberian coast, but no European ship has ever been forced beyond the Sea of Kara. Our knowledge of the Polar Asiatic shore from Behring's Straits to Novaya Zemlya is due to the Russians. The region is barren and desolate beyond description, and the ground is frozen for many feet below the surface. The most northern points of Asia have never been doubled, although Peter the Great had himself given directions in 1725 that the whole coast of Siberia should be explored. The most important discoveries due to the Russians are Behring's Straits and the Islands of New Siberia off the mouths of the Lena. Baron Wrangell, in 1820-3, explored a good deal of the North Siberian coast by means of sledges, with which, drawn by teams of dogs, he once travelled no less than 1530 miles in eleven weeks. Mr. Markham considers that Russia is entitled to rank next to England in the matter of Arctic exploration; since to it is due the survey of *more than one-third* of the threshold of the unknown Polar Region.

Having thus briefly reviewed some of the more important Polar explorations prior to the nineteenth century, let us turn our attention to the work of the present century, which has far exceeded, at least in the number and magnitude of the expeditions, any previous period. For about 40 years after Cook's voyage, no attempt was made to discover a north-west passage, until early in this century Captain Scoresby and Sir John Barrow drew the attention of the Government to the subject, and four vessels were fitted up for Polar research. Two of these—the *Isabella* and the *Alexander*—under the command respectively of John Ross and Edward Parry, were to attempt the passage by way of Davis's Straits; the other two—the *Dorothea* and the *Trent*—under the command of David Buchan and John Franklin, were to attempt to cross the Polar Sea between Spitzbergen and Greenland. Both expeditions started in 1818. Ross sailed up the east coast of Greenland, examined Jones's Sound, and turning south arrived in Lancaster Sound, returning home by way of Cape Farewell. The most important results of the voyage were some magnetic observations made by Captain Sabine. Although the other expedition under the command of Captain Buchan had as its primary object the discovery of a passage through the Polar Sea to Behring's Straits, it was also enjoined to make various electrical and magnetic observations, to take temperatures, observe the refraction of the atmosphere, the velocity of ocean currents, and the height of the tides. An astronomer accompanied the *Dorothea*. The ships skirted the west side of Spitzbergen, and anchored in Magdalena Bay early in June. After encountering very severe weather, the ships, which were much injured, and unfit to attempt further exposure in Polar seas, returned to England. During the succeeding year (1819), Franklin was sent out in command of an overland expedition destined to explore the North American Coast to the east of the Coppermine River. Dr. John Richardson and Mr. George Back (then a midshipman) served under Franklin. The intolerable hardships and privations which they endured during their journey of 5550 miles, would have deterred any hearts less stout than theirs from ever again engaging in Arctic exploration. However, Franklin again started in 1825 for the Hudson's Bay territory—wintered on the Great Bear Lake, and in the following summer surveyed the coast line to the west of the mouth of the Mackenzie River. Between 1819 and 1827, Sir Edward Parry undertook four Polar voyages. During one of these by the use of sledges he reached the highest known land, N. lat. 82° 45′ (July 23rd, 1827). The north magnetic pole of the earth was discovered by Sir James Ross during his second voyage (1829-33); it was found in lat. 70° 5′ 17″ N., and long. 96° 46′ 45″ W., on the west shore of Boothia. The amount of dip was within one minute of arc of the vertical. A cairn was erected, and the British flag placed upon it. Large extents of the Hudson's Bay Territory and the adjacent lands were surveyed by Dease, Simpson, Rae, Back, and others. Sir John Franklin's last voyage was made in 1845. Its object was to make a new attempt to discover a north-west passage. The expedition consisted of two ships, the *Erebus* and the *Terror*, specially strengthened for Arctic service, and provided with every appliance which could lessen the danger and discomfort of the undertaking. The expedition sailed on the 19th of May, and reached Disco early in July.

The ships were last seen on the 26th of July on their way to Lancaster Sound. When no tidings of the expedition came to be received, the Admiralty lost no time in sending out searching expeditions. The private and public search expeditions sent out by this country and by America between 1847 and 1859 number no less than 40. The ships were ultimately found to have been abandoned near the entrance of the Great Fish River. If proper depôts of provisions had existed, there can be no doubt that the crew might have escaped to habitable regions. Traces of their winter residence were found on Beechy Island, and a cairn was discovered on the south-west cape of the island. Sir John Franklin died in 1847. Sir Leopold McClintock traced the route of the men after the abandonment of their ships from the estuary of the Great Fish River. Here he found three skeletons of men who had perished by the way. According to the Esquimaux, 40 men (out of the 134 who had left England in 1847) reached the Great Fish River, where they all died. It was in the conduct of one of the searching expeditions for the missing crews that Captain McClure, in 1851, proved the possibility of the North-West Passage by discovering the strait which bears his name, and which, dividing Melville Island from Bank's Island, connects Beaufort Sea with Melville Sound. The passage is not, however, practicable for ships, owing to the constant accumulation of ice, and the quantity of fast ice which exists even in the height of summer. Dr. John Rae, who was sent out by the Hudson's Bay Company, was the first to bring home (in 1854) the intelligence of the fate of the *Erebus* and *Terror*. He obtained evidence from the Esquimaux that the white men had died from hunger, and he discovered many graves and skeletons, together with numerous relics. The Admiralty now concluded that the evidence of the fate of the two vessels was complete, and the promised sum of £10,000 was paid to Dr. Rae. Still Lady Franklin determined that if possible more precise information should be procured, and in 1857 she sent out the yacht *Fox*, under the command of Captain McClintock. During the first summer he made for Baffin's Bay, and was there beset with ice and enclosed. During the winter the ice drifted southwards, at the rate of more than five miles a day, for no less than 1385 miles, but in the following April (1858) the pack was broken up by a heavy gale, and the *Fox* escaped, and again made for the north. In August North Somerset was rounded, and the vessel entered Bellot's Straits, passing thence into Franklin Channel. The *Fox* wintered in Port Kennedy, and long sledge journies were made to the Magnetic Pole and elsewhere. Details of the ultimate fate of the *Erebus* and *Terror* were now learnt. One of the ships had been seen to sink, and the other was forced on shore by the ice. A number of relics were obtained from the Esquimaux on the west coast of Boothia.

Since the return of McClintock's expedition, various foreign nations have prosecuted Arctic research, while the English for the last 15 years have rested on their oars. The Americans seeking to approach the North Pole by way of Smith's Sound have reached a latitude of 82° 16′. This was effected in 1871 by Captain Hall in the *Polaris*. An expanse of open sea was seen to the far north, and was named Lincoln's Sea, while on the extreme west a coast line was discovered which was named President's Land. The Germans in 1868 sent out a privately-equipped vessel for the purpose of exploring the east coast of Greenland; but no results of importance were obtained. In 1869, a second expedition, consisting of two ships, commanded by Captain Koldewey, was again sent out to the east coast of Greenland. A certain amount of coast line below Cape Bismarck was surveyed, and the highest point reached was just above the 77° lat. The coast was carefully surveyed between the 73° and 77° N. lat.

The Swedes in 1870 explored the northern coasts of Novaya Zemlya, and in 1872 and 1873 they sent out an expedition to winter in Spitzbergen. No important results were obtained, but it is said that a new expedition will shortly be organised. A very important expedition was organised by the Austrians in 1872 under the command of Payer and Weyprecht. The object was to sail to the east of Spitzbergen, and if possible to follow the Gulf Stream into the sea which some suppose surrounds the Pole. Starting from Tromsö on July 14, the first ice was seen on the 25th, and on the 29th Novaya Zemlya came in sight. By the middle of August the vessel was near the north coast of Novaya Zemlya and was soon afterwards enclosed in the ice. Preparations for passing the winter had now to be made and the deck was converted into a house. The season had become excessively gloomy and the Arctic winter was about to commence. The sun disappeared for 109 days on October 28th, and for five months it was necessary to burn lamps. The sun appeared again on February the 16th and the severe pressure of the ice ceased. The mean temperature of the air was −31° F., and towards the close of the month it reached −51° F.; the maximum summer temperature was −45·5° F., and the mean temperature of the whole year 2·75° F. Towards the end of October, still drifting with the floe, they came in sight of land within 3 miles in lat. 79° 54′ N., and to this was given the name of Wilczek Island. The sun again deserted them on October 22nd and they passed a second polar night of 125 days. During the winter they built a house upon the floe. The cold was very severe: mercury remained frozen for more than a week, and even brandy was changed into a solid mass. When spring returned they found that their ship was still firmly fixed in the ice, and as there appeared no prospect of its being liberated even in the height of summer, they determined to abandon it (May 20th, 1874), and to make their way to Europe by means of boats and sledges. In the preceding March a sledge expedition had started for purposes of exploration; the result was the discovery of a country as large as Spitzbergen, consisting of large masses of land, intersected by fiords and skirted by islands. The large sound was named "Austria Sound," and the land on each side of it Vichy Land and Wilczek Land, and more to the north Petermann Land and King Oscar Land. The latter is above 82° N. lat. On the 20th of May, having nailed the flags to the masts of their abandoned ships, they returned to Europe.

Since the return of McClintock's expedition in 1859, and the conclusive knowledge obtained by it of the fate of the crews of the *Erebus* and *Terror*, England has taken no part in Arctic research until the great expedition which started last May. Interest was revived in the subject in 1865 when Captain Sherard Osborn read his first paper before the Geographical Society on the further prosecution of Polar exploration. In this he pointed out the various advantages to science to be derived from such researches, and the value of the training to naval officers, and he strongly advocated the route by Smith's Sound. A second paper was read on the same subject in 1872. In the same year a deputation was received by Mr. Gladstone's Government which urged the sending out of an expedition in 1874. An unsatisfactory reply was received from the Chancellor of the Exchequer, and the matter remained at rest until, after further solicitation, the application was again refused by Mr. Gladstone, and soon after the Ministry resigned, and Mr. Disraeli came into office. In August, 1874, an influential deputation waited upon Mr. Disraeli, and in the following November a letter was forwarded to Sir Henry Rawlinson which stated that "having carefully weighed the reasons set forth in support of such an expedition, the scientific advantages to be derived from it, its chances of success, as well as the importance of encouraging that spirit of maritime enterprise which has ever distinguished the English people, Her Majesty's Government have determined to lose no time in organising a suitable expedition for the purposes in view." Whereupon an Arctic Committee of old and experienced Arctic explorers was appointed, Captain George S. Nares (then in command of the *Challenger*, and formerly mate of the *Resolute* in the Arctic expedition of 1872) was chosen to command the expedition, and two ships were fitted up with every modern appliance. For various reasons the route by Smith's Sound was selected. The general instructions given to the expedition were that the ships should proceed to Disco, an island on the west coast of Greenland, lat. 70° N., where they would touch, and afterwards continue their course further north to Upernavik, where dogs and Esquimaux drivers would be taken on board. Then, if the season were favourable, the ships should enter up Smith's Sound, and should winter if practicable in Lady Franklin Strait. The *Discovery* is not to go higher than the 82 parallel, and is to act as a relief ship to secure retreat in case of need; when the *Alert* has gone as far North as possible the journey to the pole is to be attempted by means of boats and sledges. It is probable that the two ships will not winter at a distance of more than 200 miles apart. The sledge operations—a main feature of the expedition—will commence in the spring of 1876, and if necessary a relief ship will be despatched in the summer of 1877 to the entrance of Smith's Sound. When in 82° N. lat. the ship will be within 500 miles of the Pole; then, if the ice is good, sledging will be comparatively easy. A portion of the ship's company will be broken up into parties of eight or ten men with an officer, and they will start in sledges provisioned for six weeks, and will probably make about twelve miles a day.

The *Alert* is a vessel of 1045 tons and 381 H.P., and the *Discovery* of 856 tons. The crew of each ship consists of about 60 officers and men, and they are provisioned for three years. The *Alert* carries 5 tons of spirits of wine, 10 tons of bread, 85 tons of beef, pork, bacon, coffee, sugar, flour, and preserved meats; while the *Discovery* carries 4½ tons of spirits of wine, 9 tons of bread, 78 tons of beef, bacon, and preserved meats. The greatest draught of either vessel will not exceed seventeen feet. The principal article of food is *pemmican*, which is more useful in the Arctic regions than the strongest spirits. It is prepared by drying lean beef, and then pounding it to powder, to which salt and sugar are added, and finally it is mixed with its own weight of melted suet and allowed to solidify in tins, each of which contains 56 lbs. Seventy pounds of this food will support a boat's or sledge's crew of eight men for a week. A quantity of unusually strong rum forms part of the stores. There is an improved cooking apparatus, and a large quantity of fuel in the form of coal, stearine, and spirits of wine has been provided. Every possible precaution has been taken to strengthen the vessels against the severe nips which they are likely to receive from icebergs; the screws can be raised before collision with the ice, and anchors of great power are provided. A number of ice saws are shipped on board (the largest nearly 15 feet long), and an experienced ice-master will superintend their use. There are no less than eighteen boats, some of which are 25 feet long; they are constructed of mahogany covered with marine glue and canvas, with an outside planking of elm and pine and a belt of cork. The sledge arrangements are particularly complete; all previous experience has been taken into account. The sledges hold eight men each; they are made of elm, and the runners are shod with steel. They are furnished with light masts, which also serve as tent poles. The drag ropes are of whale line, 26 feet long, and the drag belts are 3 inches broad, and pass over the men's shoulders. For a journey of seven weeks the weight of a loaded sledge will be 1646 lbs., or about 235 lbs. for each of seven men to drag. The weekly allowance of food to each man exceeds 19 lbs., and consists of daily rations of 16 ozs. pemmican, 4 ozs. boiled pork, 14 ozs. biscuit, 2 ozs. preserved potatoes, 1½ ozs. chocolate, ½ oz. tea and sugar, 1 oz. strong rum, and a weekly allowance of 1¾ ozs. salt, 1 oz. curry or onion powder, ¼ oz. pepper, and 3 ozs. of tobacco. Each individual uses about 1¼ lbs. of fuel (methylated spirits of wine or crude cocoa-nut oil) weekly. By a system of auxiliary sledges one sledge can advance several weeks' journey from the ship. Suppose six sledges start in company, at the end of the first week No. 6 sledge will distribute its provisions so as to make up the full complement of the remaining five, and will then return to the ship; at the end of the second week No. 5 sledge will make up the full complement of provisions of the remaining four, and will then return to the ship, and so on for Nos. 4, 3, and 2, leaving No. 1 to reach the extreme distance. Meanwhile the sledges which have returned will re-provision, and meet the returning sledge at various points of its journey. Great distances have been traversed by means of sledges; a sledge party led by McClintock walked 1210 miles in 105 days, while the distance from Cape Parry to the North Pole is only 484 miles.

The Admiralty shortly before the expedition started issued a very valuable Manual for the use of the officers accompanying the expedition. It is entitled "A Manual of the Natural History, Geology, and Physics of Greenland and the Neighbouring Regions; together with instructions suggested by the Arctic Committee of the Royal Society for the use of the Expedition." The instructions are discussed under two headings:—*Physical Observations* and *Biology*. The former relate to astronomy, terrestrial magnetism, meteorology, atmospheric electricity, optics, and miscellaneous observations; the latter to zoology, botany, geology, and mineralogy. The important suggestions on the determination of the magnetic elements, by Prof. J. C. Adams and Captain Evans, are accompanied by three capital maps showing the lines of equal declination, inclination, and horizontal force in the Polar Regions. Sir William Thomson contributes instructions for the observation of atmospheric electricity, while Prof. G. G. Stokes gives some useful hints in regard to spectroscopic observations. The instructions extend over 86 pages, while the manual embraces 750 pages, and consists of reprints or abstracts of papers relating to the natural history and physics of the Polar Regions. The natural history is compiled by Prof. T. Rupert Jones, and the physics by Prof. W. G. Adams. The physics is divided into (1) meteorology; (2) temperature of the sea; (3) physical properties of ice; (4) tides and currents; (5) measuring the motion of glaciers; (6) observations on refraction and on air, and observations on sound; (7) terrestrial magnetism; (8) aurora borealis. The scientific members of the expedition will have enough to do if, in addition to various other observations, they attempt to follow in the footsteps of the Swedish expedition to Spitzbergen under Prof. Nordenskiold. As part of the general observational work of this expedition we find the following:—

"1. Hourly meteorological observations.

"2. Astronomical positions of stations.

"3. Pendulum and refraction observations in great cold.

"4. Hourly magnetic observations, besides observations every five minutes on two term days a month, in connection with observations at Upsala.

"5. Tides and currents."

We come now to the results which we expect to obtain from the Arctic Expedition of 1875. Before we enumerate the more special objects to be attained let us call to mind the fact that all maritime enterprise is, and ever has been, popular among the sea-loving inhabitants of these islands. And when that enterprise involves unparalleled hardships, privations, and dangers, when it may result in the discovery of new lands and seas, the probable accomplishment of that which the world has for centuries attempted in vain, the old Vikingr blood is raised to fever heat in our veins, and the adventure becomes as exciting as the bombardment of a great sea fortress, or the investment of a walled and fortified city. We may not forget that Nelson began his career in an Arctic exploring vessel, and that the undaunted heroism of Franklin and a host of Arctic explorers is almost alone in these modern days worthy to be placed on a level with that of Leonidas. Once more, we who have ever been foremost in Arctic research must not allow other nations to step in and attain the final consummation. And if there is any more to be said as to the objects of the expedition, we say that the discovery of new truths, the enlargement of the sum of human knowledge, is object enough in itself for the expedition. In this land we should have no difficulty in manning a dozen Arctic expeditions having that object alone in view. The man who enquires the immediate *practical* use of the expedition is not of one blood with these men. What, pray, was the use of Galvani's experiments with frogs' legs or Benjamin Franklin's kite experiment? The practical man may answer if he pleases. However, there is something to be said as to the practical results to be expected from the members of the expedition. They will probably not discover new whaling grounds, or stores of fossil ivory, or gold mines, or easy routes to the Indies; possibly not even seams of coal and new veins of cryolite. But they will penetrate within an area which contains 2½ millions of square miles of unexplored country, they will observe physical phenomena under extreme and unusual conditions, and they will survey many hundreds of miles of sea and land. An old Arctic explorer (Sir Edward Sabine) asserts that the completion of the circuit of Greenland and the survey of its northern and western coasts is "the greatest geographical achievement which can be attempted." Oceanic currents, tides, and deep-sea temperatures will be investigated; pendulum observations will allow us to determine the intensity of gravity at or near the pole, and will conduce to our knowledge of the figure of the earth. In meteorology we shall have determinations of the temperature and pressure of the air and the nature of prevailing winds. The magnetic and electrical results will be of peculiar interest; the spectroscope will be applied to the study of the Aurora; the nature of the electricity existing at any particular time in the air will be determined. In geology and mineralogy the field is likely to be as fruitful—a number of rare minerals have already been found in high latitudes; the existence of a palæozoic coal formation has been proved, and knowledge of its position and extent is much desired. Already the fossil flora of the east coast of Greenland has been proved to contain no less than 200 species of highly organised forms such as are not now found in the Polar Regions. As regards the existing flora of Greenland, 300 kinds of flowering plants are already known. In Zoology we have many facts to learn in regard to the migrations of birds to northern latitudes, and although the land fauna may not be extensive, the sea is full of creatures many of which have been but partially examined, and many of which are undoubtedly unknown. Finally, as to the ethnological results, it is probable that the most sterile wastes hitherto discovered in the Polar Regions were formerly inhabited. Remains have been discovered of races long since passed away. Many considerations point to the belief that, in the unexplored regions in the north of Greenland, inhabitants will be found; if so the study of these isolated peoples will be of the greatest interest; the form and measurement of their skulls, their stature, their moral intellectual condition, their whence and whither. "Snow huts will point to some devious wanderings from Boothian or American shores; while stone *yourts* would indicate a march from the coast of Siberia across a wholly unknown region." The above are some of the results to be expected from the Arctic Expedition of 1875.

On Sunday, August 29th, the *Valorous*, which had accompanied the *Alert* and *Discovery* as far as Disco, returned to England, bringing dispatches from Captain Nares. The expedition left Portsmouth on May 29th, arriving in Bantry Bay on July 2nd. Thence they made for Greenland. On the 4th of June, a heavy wind began to blow from the west, and by the 11th it had increased to a gale. The first ice was sighted on June 27th, and on the following day they were off Cape Desolation. On the 13th of June the ships parted company in the gale, and they did not join company again till June 30th in Davis's Straits. On the 6th of July they both anchored in the harbour of Godhavn, at the south-west corner of Disco, 69° N. lat. From the 6th to the 13th of July, the ships remained at Godhavn, taking in coals and other supplies from the *Valorous*. Captain Nares reports:—"We are now complete in all respects for three years from July 1st, 1875." They also took on board 44 good Greenland dogs, and two whaling-boats, which had been lost during the gale, were supplied by the *Valorous*. On Thursday, July 15th, the *Alert* and the *Discovery* left Godhavn, and on the 17th they were last seen by the *Valorous* steaming down the Waigat Sound, and ultimately disappearing behind gigantic icebergs. Soon after a deep fog settled over the waters. The Danish officials at Godhavn reported that the last winter was much colder in South Greenland than in the north, and a great deal of ice had drifted south. At Godhavn the mean temperature of the winter months was from 5° to 13° higher than the average, but the spring was unusually severe. There is every reason, according to Mr. C. R. Markham, to hope that the ships will pass through Melville Bay during this season, and reach the north water of Baffin's Bay. When this is accomplished, a depôt will be established on the northwesternmost of the Carey Islands, and the ships will proceed to Smith's Sound. The *Discovery* will winter in lat. 82, on the north shore of Lady Franklin's Strait, if suitable quarters can be found; while the *Alert* will, if possible, push up as far as 84° N. lat., and complete the remaining distance to the Pole by sledging. The sledge travelling will commence early in April, 1876, and it is proposed that six sledges and 52 men should then start, leaving only 10 men in the ship. By means of the system of auxiliary sledges described above the foremost sledge will be enabled to be absent from the ship for four months, and probably travel 500 miles from the ship. Meanwhile the *Discovery* will send out hunting and exploring parties. If no news is received of the *Alert* in 1876, the *Discovery* will attempt to communicate by means of sledges drawn by dogs; and if during the early part of 1877 the *Discovery* is still unable to obtain news of the *Alert*, the former will return to England, and it will be concluded that the *Alert*, having passed to the north-east of Greenland, will return down the east side of Greenland. Letters and dispatches will be left at Upernavik, 72° N. lat., for the last time before the vessels penetrate the unknown regions, and these letters we may expect to receive in England before Christmas. Then we shall probably hear no more of the expedition till the Autumn of 1876. Commander Markham, in a letter to Sir Henry Rawlinson, brought home in the *Valorous*, and read at the recent meeting of the British Association at Bristol, says:—"I think everything promises most favourably, and if we have only a reasonable amount of luck, I am confident we shall achieve success. We have a splendid lot of fellows, both officers and men in both ships, all eager for the fray and anxious to be at it. If we succeed in getting our ships to 83° or 84°, we shall be at the Pole in ten months' time."

No time could be more fitting than the present for an English Arctic expedition. We have enjoyed a profound peace for a number of years; the wealth of the country has prodigiously increased; taxes are low; the Exchequer is in a satisfactory condition; our most experienced seamen are at liberty to take part in the undertaking; and there is a lull in political affairs. The whole nation watches with one heart the progress of the work. In this too-practical age it does the world good to see Governments and men animated by the one desire of the discovery of new truths at any sacrifice. Whatever may be the result of the expedition, it must redound to the honour of this country and of the enlightened Government under whose auspices it was instituted.

NOTICES OF BOOKS.

The Sensations of Tone, as a Physiological Basis for the Theory of Music. By HERMANN L. F. HELMHOLTZ, M.D., formerly Professor of Physiology in the University of Heidelberg, and now Professor of Physics in the University of Berlin. Translated, with Additional Notes, by ALEXANDER G. ELLIS, B.A., F.R.S. London: Longmans and Co. 1875.

THE long looked-for translation of the *Tonempfindungen* has at length appeared, and it will be welcomed by all men of science. Hitherto those of us who can only read German with difficulty, or not at all, have made the acquaintance of certain portions of this work through Tyndall's "Lectures on Sound." Now we have before us the entire work, translated by a man most fitted for the task, and the well-known author of various papers printed by the Royal Society on collateral subjects. The original work appeared in Germany in 1862, and it has passed through three editions in that country. Its main object is to trace the precise relationships which exist between the Science of Sound and the Art of Music. It is the work of a man who, emulating the multifarious knowledge of Leonardo da Vinci, is at the same time an accomplished physiologist, physicist, mathematician, and musician; and it is the result of eight years of thought and labour.

According to the translator, "the great feature of this work is the proof that all musical sounds, whether proceeding from one or many sources, are heard by the ear as if they came from one or more distinct sources of a particular simple kind, combined by a well-known and definite law, so long as the excursions of the particles of air are small in comparison with the length of the wave, and by another and different law when those excursions are larger. From this flows the fact that any individual tone may be considered as compounded of the partial simple tones of which it is audibly composed, and the several combinations of such compound tones can be reduced to the combinations of the simple tones of which they are compounded, and of the other simple tones which result when the excursions of the particles of air are larger than usual." From it also can be derived the nature of consonance and dissonance and the theory of harmony.

The first chapter treats of "the sensation of sound in general," and at the outset a distinction is drawn between the various kinds of sound experienced by our ears, that is to say *noises* on the one hand, and *musical tones* on the other; the former being defined as being due to *non-periodic motions*—that is to say motions which do not return to the same condition after equal intervals of time; while the latter are due to *periodic motions*—that is, motions which do return to the same condition at the end of equal intervals of time. The production and propagation of sound is discussed, and the distinguishing features of musical tones—to wit, force or *loudness*, pitch or *relative height*, and quality; also the various means of indicating and examining these distinctive features. The musical tones which can be used with advantage are stated to be between 40 and 4000 vibrations in a second—a range of seven octaves; while the limits of audibility ranges over 11 octaves, from 20 to 38,000 vibrations a second. The range of the eye, on the other hand, scarcely exceeds one octave. Many terms are explained and definitions given, also a minute account of vibrations and of their graphic representation.

In the second chapter the composition of vibrations is discussed. As an analogy, the various simultaneous waves produced on water are exemplified, and we are told that we must imagine the same kind of action as taking place in the air. In a crowded ball-room, for instance, we have the various sounds of the musical instruments, the rustling dresses, the voices of men and women, and so on, and here "we have to imagine that from the mouths of men and from the deeper musical instruments there proceed waves of from 8 to 12 feet in length; from the lips of the women, waves of two to four feet in length; from the rustling of the dresses, a fine small crumple of wave, and so on: in short, a tumbled entanglement of the most different kinds of motion, complicated beyond conception." It is then shown that such composite masses of tone may be regarded as, and resolved into, simple tones. In the next chapters we plunge at once into the more complex technicalities of the subject, and the analysis of musical tones is discussed; first, by sympathetic resonance; secondly, by the ear. The whole structure of the ear is minutely discussed, and the functions of its various parts are described. Some new woodcuts, from Heule's "Manual of Anatomy," illustrate this part of the subject. An elaborate treatment of the Cortian fibres, and the office of the Cochlea, conclude the first part of the book.

The second part is "On the Interruptions of Harmony;" the third "On the Relationship of Musical Tones." Here we have an account of the development of musical style, and a division of all music into three parts, viz., the *homophonic*, or unison music of the ancients; the *polyphonic* music, with several parts, extending from the 10th to the 17th century; and, finally, *harmonic* or modern music, the special characteristic of which is the significance attributed to the harmonies.

The primitive form of music with all nations appears to be simple melody sung by a single voice, and it still remains among the Chinese, Arabs, Turks, Modern Greeks, and other peoples. Almost the only example that we now have of the "spoken song," or of something approximating to it, is in the intoning of Roman Catholic priests. Here we have differences of pitch, for emphasised words are spoken a tone higher than the rest; and modern recitative (invented by Giacomo Peri, about 1600) arose from the attempt to express these alterations of pitch by musical tones. Polyphonic music was invented by a Flemish Monk, Hucbald, in the beginning of the 10th century. It was a part music sung by two voices in fifths or fourths, with occasional doublings of the octave, and the same melodic phrase was repeated by the different voices. Modern harmonic music was induced by various causes, among which the Protestant ecclesiastical chorus is first cited, The founders of the new confession desired that the congregation itself should undertake the singing; hence harmonised chorales in which all the voices progressed at the same time had to be invented. The Roman Church also desired a reform in their music, and by order of Pope Pius IV., Palæstrina (1524-94) undertook the embellishment of ecclesiastical music.

We may give, in conclusion, a few important excerpts from the author's summary of results:—P. 564. "We are justified in assuming that historically, all music was developed from song. Afterwards the power of producing similar melodic effects was attained by means of other instruments, which had a quality of tone compounded in a manner resembling that of the human voice."

P. 568. "In the last part of my book I have endeavoured to show that the construction of scales and of harmonic tissue is a product of artistic invention, and by no means furnished by the natural formation or natural function of our ear, as it has been hitherto most generally asserted. Of course, the laws of the natural function of our ear play a great and influential part in this result. . . . . . But just as people with differently-directed tastes can erect extremely different kinds of buildings with the same stones, so also the history of music shows us that the same properties of the human ear could serve as the foundation of very different musical systems. . . . . The æsthetic problem" (in regard to music) "is thus referred to the common property of all sensual perceptions, namely, the apprehension of compound aggregates of sensations, as sensible symbols of simple external objects, without analysing them. In our usual observations on external nature, our attention is so thoroughly engaged by external objects that we are entirely unpractised in taking, as the subjects of conscious observation, any properties of our sensations themselves, which we do not know as the sensible expression of some individual external object or event." A curious and most interesting comparison of the resemblances between the relations of the musical scale and of space will be found among the concluding pages (p. 576).

An appendix of more than 200 pages will be found at the end of the work. Much of this has been added by the translator. Among other matters of interest which it contains, we may notice an account of an electro-magnetic driving machine for the siren. This machine gives perfect uniformity of rotation, and perfectly constant tones can be produced by the means. Air is driven through the siren by means of a small turbine of stiff paper. In discussing the size and construction of resonators, the author mentions that he first employed spherical glass vessels for the purpose, but now more generally vessels of brass. He also used tubes of tin and pasteboard. A table shows the exact size and capacity of resonators, adapted to tones of different pitch. A number of mathematical papers follow, and a very good index terminates the volume.

It is almost unnecessary for us to say that this already famous book will be welcomed alike by the physicist, the acoustician, and the musician. It is one of the most original works of the second half of this century, and may be placed in the same category as the "Natural Philosophy" of Thomson and Tait, and the "Electricity" of Clerk Maxwell.

Sound. Third Edition. By JOHN TYNDALL, F.R.S. London: Longmans and Co. 1875.

Six Lectures on Light. Delivered in America in 1872-73. By JOHN TYNDALL, F.R.S. Second Edition. London: Longmans and Co. 1875.

WE are very glad to welcome new editions of these standard works. One of the great merits of Dr. Tyndall as an expounder of scientific facts is that he is not alone content to read the memoirs of authors whom he is desirous of quoting, but that he himself goes through their experiments, and seldom gives an account of an experiment which he has not himself tried. His works thus become of especial value to the lecturer and science teacher. The main feature in the new edition of the "Sound" is the introduction (in chapter 7) of the author's recent experiments on "The Acoustic Transparency of the Atmosphere in relation to the Question of Fog-signalling." This subject has been so recently discussed in nearly all the scientific journals, that it will be familiar to all of us. The preface gives an account, in some detail, of the controversy between Dr. Tyndall and the United States Lighthouse Board, as to the priority of claims. A review of Dr. Tyndall's "Lectures on Light" appeared not long ago in this journal, and we have but little to add in noticing a second English edition; the only very noticeable alteration in this edition is the omission of the author's "Reply to the Edinburgh Reviewers," concerning the claims of Dr. Young, and the insertion of a portrait of Dr. Young at the commencement of the volume. In an appendix the Author gives the addresses of Profs. Barnard, Draper, and White, on the occasion of his departure from America, and the preface of the French translator of his work (the Abbé Moigno).

Natural Philosophy for General Readers and Young People. Translated and Edited from GANOT'S *Cours Elémentaire de Physique.* By E. ATKINSON, Ph.D., F.C.S., Professor of Experimental Science in the Staff College. Second Edition. London: Longmans and Co. 1875.

THIS is an abridgment of the well-known larger work of Ganot on the "Elements of Physics." It is divested of mathematical formulæ, and is specially adapted for young persons and for science classes in schools. The extent of its subject-matter may be defined by the fact that it represents the amount of physical knowledge necessary for the matriculation examination of the University of London. We are glad to notice a second edition of the work, because we believe it to be a really useful work; but we regret to notice that many clerical, and a few other, errors have not been expunged from the first edition. These will, however, be at once apparent to the teacher, and can be corrected by the student once for all. A second coloured plate has been added to this Edition, together with twenty-four new woodcuts, and twenty pages of new matter; the editor has also not contented himself with giving a mere literal translation of the French work, but has made various additions in order to render it more complete. We would suggest that in the next edition a number of well-selected questions on each chapter of the work be given, specially some questions of an arithmetical character (in regard to levers, the inclined plane, the laws of falling bodies, and of the pendulum), which are much affected now-a-days in the London Matriculation and other examinations.

A Short Manual of Heat, for the Use of Schools and Science Classes. By the Rev. A. IRVING, B.A., B.Sc. London: Longmans and Co. 1875.

An Elementary Book on Heat. By J. E. GORDON, B.A. Intended chiefly for the use of Candidates for the General Examination for the Ordinary B.A. Degree. London: Macmillan and Co. 1875.

IT is surprising that with such a book as Prof. Clerk Maxwell's "Elements of Heat," and the Clarendon Press Manual of Prof. Balfour Stewart, there should be room for any other elementary work on the subject; yet we have here two little treatises appearing within a very few months of each other. The first is by no means without merit; it embodies in an elementary form all the phenomena of heat, the arrangement is concise and comprehensive, a capital glossary of terms is given, and nearly twenty pages of questions. The book appears to us to be singularly well suited for the purposes of science teaching in schools; it contains about two Terms' work. It is a book which may be used by boys in conjunction with their school lectures, and is certainly adapted for Form questioning. It is divided into seven chapters, which treat respectively of the *Nature and Sources of Heat*, *Expansion and Thermometry*, *Changes of Physical Condition*, *Conduction of Heat*, *Specific Heat*, *Radiant Heat*, *Heat and Work*. A few simple, but in most cases sufficient, woodcuts are introduced. Mr. Gordon's book is written for a special examination (the Cambridge B.A.), and probably will not be much used beyond the circle for which it is intended. The "questions and problems" at the end are altogether deficient as to number, and we should have thought are in most instances too elementary, even for the examination for which they are intended.

Practical Hints on the Selection and Use of the Microscope. By JOHN PHIN, Editor of the "Technologist." New York: The Industrial Publication Company. 1875.

THIS little work describes in some detail the various forms of microscope, the manner of using them, and the preparation and mounting of objects; it possesses a very limited number of woodcuts, and it does not appear to us to possess any advantage over Dr. Beale's smaller book, or indeed to, by any means, come up to it in general usefulness and design.

Ure's Dictionary of Arts, Manufactures, and Mines. By R. HUNT, F.R.S. London: Longmans, Green, and Co.

URE'S "Dictionary" still maintains its place as the standard technological encyclopædia. There are, of course, treatises of some individual departments, such as metallurgy, calico-printing, manure-making, &c., which give more minute and complete instructions. But as affording a general survey of the whole field of industrial science, the work before us stands unrivalled, and may be regarded as a national trophy. The present edition has been carefully revised and brought up to the standard of the day. Many of the original articles having become obsolete, have been omitted, and others have been greatly curtailed, their subject-matter having fallen in importance since the appearance of the last edition. As an instance of such a relative decline, we may mention the prussiate of potash. A quarter of a century ago this was the ingredient necessary for the production of the most beautiful blues then known, whether upon cottons, silks, or woollens. It was also essential in the manufacture of Prussian blue, which was then a leading pigment. Now, however, blues far finer and brighter than those produced with prussiate are dyed or printed with coal-tar compounds. On the other hand, artificial ultramarine has greatly interfered with the use of Prussian blue. Hence the importance of prussiate of potash is declining, and there can be no longer the same interest felt in its manufacture. The whole field of technology—especially its chemical portion—is full of such revolutions.

As an instance of an article nearly re-written, or at least enriched with a great amount of new and important matter, we may mention that on calico-printing. Many capital discoveries have been made, or at least introduced, into practical use since the appearance of the last edition. Accordingly, we find now full notice of the methods of applying the coal-tar colours, especially the aniline-blacks—of the use of artificial alizarin and the improved extracts of madder, of the recent developments of pigment printing, and of the new indigo-vat of Schützenberger and De Lalande—improvements which may be said to have created a perfectly new epoch in this wonderful art. The kindred department of dyeing is scarcely treated in as thorough-going and as practical a manner. In the article on sulphuric acid, we are glad to find that the recent important researches of Mr. H. A. Smith have not been passed unnoticed. He maintains that the best form of chambers should be rather long than high, being about 150 feet in length, 35 to 30 feet in width, and 10 to 12 feet in height.

The account of the artificial soda, or, as it is generally called, alkali-manufacture, includes brief notices of the new methods of Mr. Tilghman and of MM. Schlœsing and Rolland, otherwise known as the ammonia-process. The arrangements for effecting the condensation of the muriatic gas, as required under the Alkali Act of 1863, are also described and illustrated with drawings of the towers at the celebrated works of Messrs. Alhusen.

In short, it may generally be said that few recent improvements in any branch of manufactures have been entirely overlooked. It would be, of course, easy to suggest additions which might have been made, and which would, doubtless, increase the value of the work. But the great point in a compilation of this kind is to include all that is really essential without rendering the result too bulky, and consequently too costly. This end, we think, the editors have reached to a very satisfactory degree. The present edition is a book which no manufacturer, merchant, miner, or technologist, should be without.

The Skull and Brain; their Indications of Character and Anatomical Relations. By NICHOLAS MORGAN. London: Longmans, Green, and Co.

A WORK on phrenology is, in these days, quite a portent. Some 30 or 40 years ago the case was different. Every large town and many a small one had its phrenological society; every popular literary institute had a class for the study of cerebral development in connection with character. We saw phrenological busts in shop-windows and in the libraries of our friends. We heard the subject continually discussed, not merely at gatherings of scientific men, but even in general society. Works assailing or defending the system were published, and received wide attention. Now all this is changed. The phrenological societies are, we believe, for the most part, defunct, and their museums broken up or disused. There does not appear to be, numerous as scientific and semi-scientific periodicals have become, a single phrenological journal published in London. We cannot lay our hands on any review-article on the subject which has been issued within some 15 years; nor, indeed, does our author refer to any such. Surely this fact—the gradual but general disappearance of phrenology from public attention in England—is one which Mr. Morgan should have noticed, and, if possible, explained. But he seems to have ignored it altogether.

Again, Mr. Morgan quotes without contradiction, from "Blackwood's Magazine" for 1857, a passage by Mr. G. H. Lewes, in which the latter declares that though "phrenology was born in Germany and reared in France, it has not standing-room in either country." On this he comments as follows: "This is highly suggestive. The seed of phrenology germinates and grows vigorously in these countries (England and Scotland), because it is sown in the soil of thought and is manured by impartial investigation, and warmed by the sunshine of sincerity. No wonder, then, that it withstands the blight of ridicule and the storms of prejudice." To this somewhat rhetorical passage we must object that it overlooks the recent decline of phrenology in Britain. Further, neither Mr. Lewes nor Mr. Morgan accounts in a satisfactory manner for the failure of phrenology on the Continent, as compared with its former popularity in England. "Thought," "impartial investigation," and "sincerity," are assuredly not the exclusive attributes of our island. Political investigations, indeed, when taking a direction unwelcome to the authorities, may have been suppressed in Germany; but scientific speculation has assuredly not been fettered, either by the censorship or by "Mrs. Grundy." We doubt, indeed, the power of the latter authority to hinder a German professor from following out to its remotest logical consequences any system for which he has sufficient evidence.

We do not, of course, mean to urge that either the decay of phrenology in Britain, or its rejection in Germany, is any direct argument against its truth. Still both are facts which an apologist like Mr. Morgan would have done well to examine.

The work before us begins with a survey of the objections to phrenology, those especially urged by Mr. Lewes in his "History of Philosophy," as published in 1871, and in his paper on "Phrenology in France," contained in "Blackwood's Magazine," for December, 1857. Mr. Lewes is charged with a strong anti-phrenological bias, and with the ready acceptance, without due verification, of evidence telling against the system. Thus, on the authority of M. Piesse ("La Médecine et les Médecins," Paris, 1857), he declares the head of the first Napoleon to have been "decidedly small." Mr. Morgan, from actual measurements, made on "an authentic copy of Dr. Antomarchi's cast of him," asserts that it was "considerably larger than the average European male head," exceeding in most directions the heads of S. T. Coleridge and Dr. A. Combe. The researches of Dr. Ferrier, which, by the way, will lay him open to the vengeance of the anti-vivisectionists, are cited in proof that the individual convolutions of the brain are separate and distinct organs. It is suggested that possibly Mr. Lewes "will deem it advisable in the next edition of the "History of Philosophy" to modify his views, and to eliminate the gratuitous assertion that the researches of anatomists have disproved every point advanced by Gall, in the same way as he found it necessary to re-write many portions of the last edition, so as to bring them more in consonance with the spirit of the times."

Dr. Ferrier's results, though accepted in support of the view that the brain consists of a number of distinct organs, are otherwise called strongly in question. This relates especially to his announcement that the cerebellum has no connection with the sexual instinct, since its excitement by a Faradic current failed to elicit any amatory symptoms.

Incidentally, too, Dr. Carpenter is criticised. He maintains* "that the *posterior* lobes of the cerebrum are the instruments, *not* (as maintained by phrenologists) of those passions and propensities which man shares with the lower animals, but of attributes peculiar to man, which we fairly may suppose to consist in such mental operations of a peculiar intellectual character as do not express themselves in bodily action."

Our author remarks that the brains of idiots are generally remarkable for the largeness of these parts and the smallness of the anterior lobes, whilst those persons who are marked for intellectual power are, as a rule, equally noted for the extraordinary size of the anterior lobes.

We should add that the number of attributes peculiar to man will be found, upon more careful and impartial scrutiny, to become "fine by degrees, and beautifully less." The last objection to phrenology which the author takes into consideration is the timeworn cavil that it leads to fatalism—a curious charge when brought, as it often was, by the followers of Calvin! It must be remembered that the plea of necessity is felt to be no longer any bar to the punishment of criminals. Whether a given man can "help" committing a murder or not, still, if he has been guilty of such a deed, society is in self-defence justified in his elimination.

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* Mental Physiology, pp. 714, 715.

A Digest of the Reported Cases Relating to the Law and Practice of Letters Patent for Inventions, Decided from the Passing of the Statute of Monopolies to the Present Time. By CLEMENT HIGGINS, M.A., F.C.S., Barrister-at-Law. London: Butterworths.

THE rights of inventors, the nature and even the very existence of patent-laws, are at present under examination and may be said to be trembling in the balance. A number of persons, noisy if not numerous, and strong in influence if not in argument, contend that patents are a hindrance instead of a benefit to manufactures, and deny the exclusive claim of the inventor to the beneficial use of his own ideas. That a view so essentially communistic should for one moment be tolerated in property-loving England may seem at first sight singular. But it is in reality the outcome of a principle but too common. Your *sans cullotte* communist, who has nothing in his purse, denounces property as robbery, and clamours for the confiscation of landed estates. Your capitalist, who has nothing in his head, denounces property in ideas, and seeks to confiscate all inventions for the good of the public, by which he means himself.

There are, moreover, two words commonly used in connection with patents which act upon the "rump" of the Manchester school in the same manner as a red cloth does upon a bull. We speak of obtaining *protection* for an invention, and we refer in treating of patents to the statute of *Monopolies*. These two unfortunate terms do the mischief. They are used, to be sure, in a sense quite different from what they bore in the great anti-corn-law agitation. But a free-trader when once he suspects economic heresy overlooks such distinctions. It is, of course, incontrovertible that if any kind of property should be sacred and inviolable, property in inventions should have precedence. The inventor may justly ask the memorable question "May not I do what I will with my own?" for he has created it. If a man may use our inventions against our will, and without recompense, *a fortiori* he is entitled to appropriate our money, even our personal labour, for his own purposes. If the anti-patent law agitators can show us any better way in which the interests of the inventor may be secured and recognised, we shall be well content. If not, we must protest against their views, and against the Bill for the "Amendment" of the Patent Laws now under the consideration of Parliament.

The work before us is a valuable and a welcome contribution to a knowledge of our present patent-law system, a system which, with all its admitted imperfections, has done much for our national manufacturers and much for industrial science. Those very men who are now barking against the system owe to it, indirectly, everything. It therefore deserves that we should make it the subject of careful study, so that its blemishes and shortcomings may be removed without the sacrifice of its merits.

Mr. Higgins has given us, in a very natural and convenient order, the recorded decisions of the courts of Law and Equity on every branch of this great and difficult subject. From these decisions the state of the law upon any point connected with patents may be deduced.

The learned author has not, indeed, sought to explain or justify the decisions, to reconcile real or apparent discrepancies, or to furnish any note or comment whatever. Had he done so the volume might have been expanded to an extent which would have greatly interfered with its utility. But he enables even persons not learned in the law to form a clear notion of the circumstances and conditions under which patents are granted, and of the rights, duties, and liabilities of patentees. The decisions are grouped under such heads as persons interested would naturally expect, and within these divisions they are arranged in chronological order. Does the reader wish to know what may be legally made the subject-matter of letters-patent? He finds that head in the copious table of contents and under it the decisions in point. Does he wish for information on sale and assignment, on licences and royalties, on joint ownership, or on infringement? It is all here. The work is further provided with a "table of cases" showing the original documents in which the decisions are found and the paragraphs in which they are quoted in this digest. There is also a very elaborate index. In fine, we must pronounce the book not only invaluable to patent agents, but likely to protect inventors, patentees, and manufacturers from much unnecessary trouble, anxiety, and expense.

Corals and Coral Islands. By James D. Dana, LL.D. London: Sampson Low, Marston, Low, and Searle.

Corals have long been a subject for conflicting theories, and a theme for sentimental declamation. They were once classified as vegetables. By certain speculators they are even yet imagined to be purely mineral developments, a kind of crystallisation, due to electrical forces, which Dr. Dana justly characterises as "the first and last appeal of ignorance." Some even of those who cannot deny the evidence of their animal nature entertain the wildest notions as to their manner of life and as to the mode in which coral reefs are produced. Those delicately branched and laminated structures, white, yellow, or red, which adorn our museums under the name of "corals," are commonly said to be the "work" of certain minute worms, or worse still of "insects," —a term which so applied always sets our teeth on edge. These little creatures by their "toil" and "skill" are supposed to build up islands from out of the profoundest depths of ocean. Each branch of coral is supposed to be "the constructed hive or house of a swarm of polyps, like the comb of the bee or the hillock of a colony of plants." The pores are described as cells into which the individual "insects" can retire for shelter or concealment.

All this, and more of a similar tendency, may be read in certain popular treatises on natural history, or, for those who prefer verse to prose, in Montgomery's "Pelican Island," concerning which our author remarks, with perfect truth, that "more error in the same compass could scarcely be found." In sober reality, the polyps elaborate coral, not by skill or toil, but by unconscious secretion, just as the bird forms the shell of its egg, or the quadruped develops its bones. Instead of the coral being a house, it is rather a skeleton, having its place within the animal. Polyps propagate by a process of "budding" as well as by ova, the former method being more general among the coral-forming species. This accounts for the branch-like structure of the corals.

The notion of polyps building up islands from the bottom of deep seas is now known to be mythological. Coral is certainly found at great depths, but it is never discovered in a living state beyond twenty-five fathoms. Hence, the origin of coral reefs was wrapped in mystery until Darwin, during the celebrated surveying voyage of the *Beagle*, succeeded in solving the question. Coral cannot live below twenty-five fathoms, and yet it is found extending downwards to far greater depths, dead in the lower regions, but living above. This is only possible on the supposition that the foundations upon which the reef was "built" have gradually sunk down, whilst the upper part continues to be extended, so as to keep its level, or even to rise to a certain height above the surface. Hence, these reefs become of the profoundest interest to geologists, serving as evidence of areas of subsidence, and, in tropical seas at least, marking the position of islands which have long ago disappeared.

Dr. Dana's views on the origin and signification of coral-reefs coincide in all main points with those of Darwin. The theory of our great English naturalist, which the author has studied, not in the closet, but among the living objects of which it treats, gave him, as he informs us, on his ocean journeys, "not only light but delight, since facts found their places under it so readily, and derived from it so wide a bearing on the earth's history." It is still more important for us to learn that Darwin's work on "Coral Reefs" appeared at a time when the author's "Report" was already in manuscript. The conclusions which these two eminent explorers had in a great measure independently reached were for the most part the same. It need scarcely be said that such a coincidence furnishes a very strong presumption in favour of the correctness of the theory.

Dr. Dana's work is well arranged. It may be divided into a zoological and a geological portion. In the former he describes and figures the principal species of polyps, hydroids, bryozoans, nullipores, and corallines. He then treats of their distribution in latitude and in depth, of the influence of local causes upon their development, and on their rate of growth. He then considers the structure of coral reefs and islands, their formation, and the causes modifying their form and growth, so as to produce barrier and fringing reefs and completed atolls. The author next surveys the geographical distribution of coral reefs and islands and passes on to the changes of level, in the Pacific Ocean especially, of which they afford us evidence. Finally he considers the geological bearing of the facts detailed in the earlier portions of the work, especially as regards the origin and characteristics of the great limestone formations. The work is plentifully and usefully illustrated,—two points which do not always go together,—and is furnished with an isochrymal chart of the oceans to illustrate the geographical distribution of corals and other oceanic species. There are also a good table of contents and index, a list of authors and memoirs quoted, and a list of the species described in the author's classical "Report on Zoophytes." We consider this a popular book in the highest sense of the word—clear, intelligible, readable, but at the same time thorough-going and accurate. Every student of natural history, geology, or physical geography ought to give this work a place in his library.

Chemical Examination of Alcoholic Liquors. By ALBERT B. PRESCOTT, M.D. New York: D. Van Nostrand.

THE objects of this manual, as stated in the preface, are to give in outline the chemistry of alcoholic liquors, including their current impurities and adulterations, in such terms as to be understood by persons having only an ordinary acquaintance with chemical science; and secondly, to furnish directions, as far as possible, for an efficient chemical examination; not more elaborate than is required for commercial, hygienic, and legal purposes, and containing all details except such as are to be found in every rudimentary treatise on chemical analysis. The writer, we are happy to find, holds it to be of absolute importance to society that all articles used as foods, medicines, or beverages be made subject to strict examination by authority of the law, and that impurities and additions be systematically exposed and suppressed." The author carries out his plan in a very satisfactory manner. Under each alcoholic liquor he describes the normal constituents, and then the fraudulent additions or substitutions.

Thus we are informed that genuine wine (the fermented juice of the grape without any addition) contains:—

(*a*). Alcohol, 7 to 20 per cent. by weight.
(*b*). Non-volatile substances, 3 to 10 per cent., including—
  Grape-sugar 0·1 to 3 per cent (in a few varieties of wine 10, 13, 14 per cent.)
  Free fixed acid, equal 0·3 to 0·6 of tartaric.
  Tannic acid, 0·08 to 0·20 per cent.
  Glycerine, 0·1 to 0·5 (maximum 2·0 per cent.)
  Albumen (nitrogen from 0·02 to 0·06 per cent.)
  Gum, pectin, fat, wax, colour, ash, 0·17 to 0·27 per cent. (Potassic phosphate, fully two-thirds the ash.)
  Tartrate of ethyl (decomposed upon evaporation).
(*c*). Volatile substances, besides alcohol and water.
  Ethers.
  Fusel oil.
  Acetic acid (0·06 to 0·12 per cent.)

We must remark that the author does not use the term "fusel" as a mere synonym for amylic alcohol, but extends it to all those products of fermentation which distil at a temperature higher than the boiling-point of ethylic alcohol. He quotes from Schmidt's "Jahrbücher Gesam. Med.," 1871, B. 149, p. 264, some interesting information on the physiological action of these compounds, which fully confirms the prevalent notion of their insalubrity. Amylic alcohol, it appears, produces poisonous effects, closely resembling those of ethylic alcohol, but of fifteen times greater intensity. Frogs were floated in a 0·002 solution of the alcohol (one part to 500 parts of water), and then in stronger solutions, and the effects of depressed action of the heart, congestion, anæsthesia, and death were timed. Amylic alcohol produced the same effects in the same time as did ethylic alcohol of fifteen times greater concentration or butylic alcohol of three times greater concentration; from which it was inferred that the poisonous action of butylic alcohol is five times more intense than that of ethylic acohol in the same quantity. Rabuteau also experimented on himself, taking from four to eight grains of amylic alcohol in a glass of wine, and the results confirmed the conclusions given above. On the other hand, Hermann, in his "Alcoholism in Russia," maintains that *delirium tremens* and acute alcoholism are not found more likely to result from the use of cheap spirits with much fusel oil than from the consumption of purer qualities. We may here state that in Poland and certain parts of eastern Germany, where highly fuseliferous potato-spirit is extensively consumed, the belief in its specially injurious character is common, both among professional and non-professional observers.

Apropos of poisonous beverages, our attention naturally turns to the worst of the class, absinthe. Dr. Prescott describes it as containing 40 to 60 per cent. by volume of alcohol, and several per cent of essential oils, those of wormwood, cinnamon, cloves, anise, and angelica being chiefly used, and coloured green with leaves of spinach and parsley, occasionally also with acetate of copper or with a mixture of indigo and gamboge. Doubtless by an oversight, he makes no allusion to the specifically noxious quality of this liqueur as compared with alcohol. We certainly think it essential that the manufacture, importation, or sale of this and of any analogous compound should be, on obvious sanitary grounds, totally prohibited.

Returning to wine, we find, among the list of impurities or additions, sugar, to increase the alcoholic strength of wines which otherwise would be weak. The author mentions that not more than 20 per cent of alcohol can be obtained by fermentation. If a greater amount be detected, the wine is sophisticated by the addition of spirits, generally of a low quality. Glycerine is occasionally added to the extent of 1 to 3 per cent., and if of good quality, free from traces of lead, is one of the most pardonable additions.

Calcined gypsum is sometimes added "to prevent viscous fermentation, to restore ropy wines, to fix colour, and to remove water." It is sometimes sprinkled upon the grapes, constituting the sin of plastering. This evil practice has not only been long and widely followed by the manufacturers—we use the term advisedly instead of growers—of sherry, but is finding its way into Australia. The result is that sulphate of potash is formed in the wine to an unnatural extent; its harsh, saline bitterness greatly injuring the flavour, and its well known action upon the heart rendering it hurtful, even dangerous. We should propose that all wines found to contain sulphuric acid in combination that above the normal amount should be at once condemned and run out into the river. Of course a brisk debate would then arise as to the normal quantity, and those chemists who stated the amount correctly would be pronounced "incompetent" by self-constituted judges. It is an important fact that in the juice of the grape magnesian salts predominate, whilst the fruits with which spurious imitations are chiefly got up are richer in calcium compounds. True wine contains malic and tartaric acids, whilst sham wines are often rich in citric, and, *horribile dictu*, in oxalic. The latter prevails when the fermented juice of rhubarb plays a leading part in the manufacture. Cane-sugar is never found in genuine wine, and its presence is, therefore, a mark of fraud. The author very judiciously remarks that "the artificial production of wines is not, like that of brandy, a task which chemical skill can hope to accomplish. Besides the great complexity of the ethers, the solid extractives are requisite. Then the peculiarity—in many cases the commercial value—of an actual wine depends upon certain proportions of the constituents named above, which proportions the chemist cannot fully determine. The ethers of wine elude quantitative analysis. Moreover there are doubtless substances in wine not identified. It may be perfectly true that a mixture of pure alcohol, water, glucose, bitartrate, and ethers, may be made in such carefully adjusted proportions that it will probably be capable of producing whatever effect wine would produce upon the system, and indeed may be less objectionable for administration, more agreeable, and more saleable than are many grades of actual wine; yet such a mixture is not actual wine, and should not be presented as such."

In treating of malt liquors, the author does not endorse the view that strychnia, if added to beer, would be thrown out of solution by the tannic acid of the hop. The tannin of the hop does not remain in beer. "Moreover the insolubility of the tannate of strychnia in 20,000 parts of water is by no means assured, and with the solvent action of acetic acid, as in beer, is quite improbable." Further, where strychnia is used, the hops will either be greatly reduced in amount or dispensed with altogether.

We may finally characterise this work as a valuable complement to the labours of Mr. Allen, Professor Wanklyn, and others of the much-abused public analysts who are successfully striving to place the chemical examination of food upon a sound and sure basis.

Report of the Geological Survey of the State of Missouri, including Field Work of 1873-1874. With 91 Illustrations and an Atlas. By GARLAND C. BROADHEAD, State Geologist. Jefferson City: Regan and Carter.

THIS is a decidedly unreadable book, and yet as a work of reference we must pronounce it a most valuable contribution to geological literature—a store-house of authenticated facts placed at the disposal of men of science.

After a historical sketch of the progress of mining and metallurgy in the State of Missouri, we find an account of its caves, water-supplies, soils, timber, minerals, and rocks. Then follow more detailed notices of the geology of the various counties, and a description of the lead regions of south-western and of central and south-eastern Missouri, and of the iron ore deposits of the State. In the appendices are given a description of the lead-mines of upper Louisiana, the metallic statistics and mineral springs of Missouri, and an abstract of the chemical analyses executed by the department. These latter refer chiefly to coals, limestones, waters, lead and zinc ores, and slags.

The presence of cadmium in the blende from the south-western region is a fact of some interest. In its determination the samples usually taken were of the weight of 20 grms. The cadmium was first thrown down by means of sulphuretted hydrogen, but as the precipitate was accompanied by much zinc it was re-dissolved in hydrochloric acid, and again thrown down in the same manner. It was next dissolved in sulphuric acid, the slightest excess being carefully avoided, and a third time precipitated as sulphide. This time the separation was found to be perfect. The cadmium sulphide was then re-dissolved, precipitated, and finally weighed as oxide. The cyanide method was also used for the separation of zinc and cadmium, and the mean results obtained all agreed within 0·05 per cent.

The mineral productions of the State appear extensive and varied. Iron occurs in the forms of bog-ore, limonite, goethite, red hematite, spathic ores, ankerite, specular iron, and sulphurets, The latter is generally diffused, "occurring in most of the coals, shales, and slates, and scarcely any limestone is free from it." Gold is found, though not to any great extent, in the drift sands of North Missouri. Silver is found only associated with lead. Blende abounds at Granby and Joplin and in other parts of the South-west; it is also found in the coal "pockets" of Central Missouri, in the lead mines of the same district, in the St. Louis limestone, and in the coal-measure limestone. "Iron-stone concretions often inclose a nucleus of zinc-blende. Fragments of plant-remains often have minute cracks filled with blende, and it occurs in the interior of fossil shells." Silicate and carbonate of zinc occur at Granby and Joplin, and zinc-bloom, though rarely in the central and southern parts of the State. Greenockite (cadmium sulphide) is associated with blende in the South-west. Copper is not specially mined at any part of the State, though it exists in small quantities widely diffused, as malachite and as copper pyrites. Nickel and cobalt occur as sulphides and arsenides, distributed through the galena, especially at Mine La Motte. At the Bluff Diggings the ore was found to contain—

Copper	1·00
Nickel	18·10
Cobalt	13·90
Lead	17·45 per cent.

These ores are not washed, but alternate layers of the ore and of charcoal are placed on a heap and roasted. When thus freed from sulphur they are smelted in a blast-furnace, which yields a matte of nickel and cobalt, some little copper, and traces of lead. Its sale price on the spot is 75 cents per pound.

Millerite (nickel sulphide) is found in the St. Louis limestone in beautiful hair-like crystals, occupying drusy cavities and resting on calcite or on fluor-spar. Lead occurs in profusion as galena and carbonate. Pyromorphite (lead-phosphate) is more rare. Wolfram is found in Madison County, and manganese and manganiferous iron in Iron County.

Sulphate of baryta, locally known as "tiff," is found in the lead mines of Cole, Miller, and Morgan, and is used, as in Europe, for adulterating white-lead. Mineral oils are widely diffused, but nowhere occur in quantity. The saccharoid sandstone, which is 100 feet thick at Cape Girardeau and 133 feet at St. Charles and Warren, is an excellent material for the glass manufacture.

Electricity: its Theory, Sources, and Applications. By JOHN T. SPRAGUE, Member of the Society of Telegraph Engineers. London: E. and F. N. Spon. 1875.

THE Author having contributed to the "English Mechanic" a number of articles on Electricity, now collects them for the first time; and his object in making this compilation has been to review and systematise the leading facts of the science, and thus to provide for general readers, interested in the subject, a *catalogue raisonnée*. The work is divided into twelve chapters, followed by a short "Dictionary of Terms." The first chapter is introductory, and at the outset our knowledge is divided into Metaphysics and Physics, the latter being designated "the basis of all our real knowledge." Various definitions follow:—Matter, elements, atoms, atomicity, molecules, chemical notation, ether. These definitions are slight, and sometimes very incomplete, and even inaccurate. Thus we are told that "the atom has several relations to force, while gravity, heat, and chemical affinity are the only forces specified." Again, of the ether it is said that astronomy affords us actual evidence of its existence, yet that we know "absolutely nothing" about it. Although, indeed, astronomy furnishes one proof of its existence, it is, we think, by no means the principal proof, and no one who has studied the phenomena of polarised light can say that we know absolutely nothing of the ether. In discussing valency, we are told that "one of the oldest ideas of the atom was that matter had no real existence, and that atoms were simply centres of force;" but surely this was one of the later phases in the history of the atomic theory. The division of molecules into "molecules which are also atoms," and "molecules formed of two similar atoms," is singularly perplexing to the student, and surely a very novel idea. Finally, we have a classification of the forces, and an expression of the belief that electricity, like heat, is a mode of motion. Altogether we think this introductory chapter will be of little use to the general reader unless he has already thought over for himself the various subjects which it discusses, and can thus discriminate between hypotheses and facts, and at the same time supplement the somewhat partial knowledge which it conveys. The second chapter, which occupies about one-seventh of the book, treats of static electricity. This subject is treated in a somewhat abstruse and occasionally very hypothetical form: for example (p. 22) it is pure hypothesis to assume that the molecules of bodies are spherical, and that if they are caused to rotate about a vertical axis, they will become ellipsoidal, and that a substance is then said to be polarised. The theory of induction developed therefrom, which we are told is very different from Faraday's theory, is equally hypothetical. The actual subject of induction (p. 31) receives but slight discussion, and the author passes on at once to electrical machines. The action of the Holtz machine is described, but in so complicated a form that we are convinced no general reader could follow it for a moment. That important instrument, the Leyden jar, is neither figured nor described, because it is so well known. The third chapter treats of magnetism, the fourth of galvanic batteries. This latter contains a very fair account of the existing batteries, including several of the new forms, and at the end of the chapter a list of 11 batteries is given, with the various purposes for which they are most suitable. The fifth chapter, occupying more than 50 pages, is on the very important subject of electrical *measurement*; the author has evidently given much attention to the matter, and the account which he gives is valuable, and will be appreciated by those engaged in practical telegraph work, as also will the following chapter on conductivity and resistance. In the seventh chapter the *current* is discussed, and this is commenced by a statement of Ohm's law. A curious diagram on p. 204 attempts to explain the action of the galvanic current by a mechanical analogy. This chapter is appropriately followed by one on electromotive force, wherein will be found (p. 217) a table giving the value of no less than 29 units. Final chapters treat of electrolysis, electro-magnetism, and electro-metallurgy. A short dictionary of terms concludes the work. The Electric Telegraph oddly enough receives only a few pages of notice at the conclusion of the book. One of the first things we look for now-a-days in a work on Electricity is a definition of that much-used (and by beginners much-abused) word *Potential*. Mr. Sprague does not employ it, because, according to his view, "at present it has really no definite and accepted meaning"; in support of this assertion he quotes the definitions of Latimer Clark and Fleeming Jenkin, and shows that they are at variance. He con siders that the word is almost always used in place of tension or electromotive force. Again, the Farad is a term which does not always receive the same definition.

The book bears evidence of much thought, but it is somewhat patchy, and very jerky and variable in style. We do not think that it can be useful to the general reader, or indeed to anyone but the advanced student. To him we recommend a perusal of the work. It is often eminently suggestive, and if he be already well grounded in electrical matters, he will find much in Mr. Sprague's book to excite his thinking faculties.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE limited space at our disposal will not allow of more than a brief notice of the 1875 meeting of the British Association, which commenced on August 25th at Bristol. The local committee, of which Mr. W. Lant Carpenter and Mr. F. Clarke were secretaries, had made every possible arrangement for the comfort and convenience of the visitors. There were not wanting incidents to remind the members of the rapid progress in science during the 39 years which had elapsed since the previous meeting of the Association in Bristol. It was at Bristol in 1836 that the Mechanical Section was first instituted, and the President in his inaugural address drew attention to the fact that at a meeting of that section Dr. Lardner expressed the opinion that no steamboat would ever cross the Atlantic. Shortly after, however, the *Sirius* steamed from Bristol to New York in 17 days, and was soon followed by the *Great Western*, which made the homeward passage in 13½ days. We have also been reminded that at the Bristol meeting in 1836 Andrew Crosse expressed the belief that by means of electricity instantaneous communication with all parts of the world would one day be accomplished. At the second *soirée* this year a display of telegraphic instruments was made by the Post Office and telegraphic communications were maintained with Paris, London, and other places throughout the evening.

In introducing Sir John Hawkshaw as President for the year, Prof. Tyndall said: "In him I doubt not you will have a wise and prudent head, a leader not likely to be caught up into atmospheric vortices of speculation about things organic or inorganic, about mind or matters beyond the reach of mind, but one who, struggling Antæus-like, with his subject here to-night, will know how to maintain throughout a refreshing contact with his mother earth. I have looked forward for some time to the crowning act still in prospect of his professional career, to give our perturbed spirits rest in crossing the Channel in visiting our fair sister France. But pending that great achievement, it is his enviable lot to steer this British Association through calm waters to a haven of, at all events, temporary rest—rest all the more sweet and needful from the tempestuous weather which rasher navigators who preceded him thought it their duty to encounter rather than to avoid. To his strong hand I commit the helm of our noble barque, wishing him not only success, but triumph in that task he has undertaken, and which I now call upon him to fulfil."

Sir John Hawkshaw, F.R.S., delivered a long and able address on the origin, history, and progress of the science of engineering.

Several of the sectional addresses possessed unusual merit; they do not, however, admit of sufficient compression for us to give abstracts of them. The papers on subjects connected with physical science were not so numerous as on some former occasions. Several of those read, however, were of great value.

Professor Everett presented the report of the Underground Temperature Committee, which has now been in existence eight years. He gave an interesting account of investigations in the St. Gothard Tunnel. The distance now penetrated is more than a mile and a half at each end, and the temperature is found to be higher in the Swiss than in the Italian end, although the thickness of rock overhead is less. The length of the tunnel when completed will be nine miles, and the greatest depth beneath the surface two miles.

Dr. Guthrie, F.R.S., read a paper "On the Measurement of Wave Motion." By means of cylindrical troughs, he shows that the rate of undulation varies inversely as the square root of the diameter. This confirms the assertion that the rate of wave progress varies directly as the square root of the wave length; because the rate of recurrence must vary as the rate of progression divided by the path.

Dr. J. Hopkinson read an important paper by Professor Stokes and himself "On the Optical Properties of Titano-Silicic Glass." The principal object for the experiments, viz., the production of a titano-silicic glass suitable for destroying the secondary spectrum in an achromatic combination, has not been attained.

Professor Osborne Reynolds read a paper "On the Refraction of Sound by the Atmosphere." By means of an electric bell, the author found that with a cloudy sky and no dew the sound could be heard farther with than against the wind; but with a clear sky and a heavy dew, the sound could be heard as far against a light wind as with it.

Mr. J. A. Fleming read a paper "On the Decomposition of an Electrolyte by Magneto-Electric Induction." This paper appears in full in "The Electrical News and Telegraphic Reporter."

The Rev. S. J. Perry, of Stoneyhurst College, made some remarks on the transit of Venus. With regard to the stations in the North, Father Perry said they were left to the care of the Russians, and the English, Americans, Germans, and others confined their observations to the southern hemisphere. As it was mid-winter the sun was very nearly on the line of the southern tropics and nearly vertical over the eastern border of Australia. There were primarily five English expeditions, but as these were subdivided, there were nearly 20 stations of observation. His station was Kerguelen, to the south-west of Australia. On the morning of the transit they divided into three parties, and were so placed that, with the Americans, they formed four parties, about eight miles distant from each other. They saw the sun very well until almost the time that Venus was coming on to the sun's disc, and they had the external contact as well as could be expected, for there never could be absolute certainty with regard to such a point. They continued very well until they had taken the bisection by the planet of the sun's disc, but then there was just one little cloud that came and placed itself right over the planet and remained till 10 minutes after the commencement of the transit. At the other stations they were able to make observations of the ingress. At his station they were able to get very good observations and photographs of the internal points of contact and also of egress. The results of the observations would not be ascertained for at least 7 years, the determination of their longitude occupying a very long time.

M. Janssen contributed a paper on the same subject. By using coloured glasses, so selected as to allow the light of the corona to pass, he succeeded in seeing the planet for 10 minutes previous to its entering upon the sun's disc. His observations establish the existence of an atmosphere to Venus.

Sir William Thomson illustrated by diagrams the description of his experiments "On the Effects of Stress on the Magnetism of Soft Iron." With steel wire the magnetism diminished when weights were attached to the wire and increased when they were taken off, but when iron wire almost as soft as lead was used these results were reversed.

Professor W. F. Barrett read a paper on the Effects of Heat on the Molecular Structure of Steel. In the course of experiments he had found that steel of any thickness, if heated to a certain temperature, ceases to expand, and the steel wire does not increase in temperature. The length of time during which this abnormal condition lasts varies with the thickness of the wire and the rapidity with which it can be heated. No further change takes place till the heat is cut off, and then when the point is reached at which the change took place, an actual increase in temperature occurs sufficiently great to cause the wire to glow with a red heat. It was strange that this afterglow had not been noticed before.

Some interesting experiments on magnetised rings, plates, and discs of hardened steel were exhibited by Mr. P. Braham.

Mr. Glaisher presented the report of the Committee on Luminous Meteors. A mass of meteoric iron fell on the 24th August, 1873, at Maysville, California, and was one of the very few pieces of metallic iron the actual descent of which had been witnessed. In the following month a number of meteorites fell near Khairpur, in the Punjaub, and it is also related that in the month of December, when the British army halted on the banks of the Prah, an aërolite fell in the market-place at Coomassie, and was regarded as a portent of evil by the natives. On the 14th and 20th of May aërolites fell at Castalia, in North Carolina, and the last stone fall of the present year took place on the 12th February, 1875, near Iowa. In England no detonatory meteor had been observed this year, and the brightest meteor occurred on the 1st September, 1874.

A meteor burst with a loud detonation over Paris on the 10th February, of great size and brilliancy, and left a cloud like a streak of light in its track for nearly half an hour. No duplicate observation of it was obtained in England. Another fireball fell at Orleans on the 9th March, and of this two good observations were obtained in England—in London and Essex. The problem of the connection between comets and meteors had now become so great as to pass beyond the power of the Association to grapple with it in its fullest extent. There was a great deal of work yet to be done, and he was glad to state that Professor Le Verrier, of Paris, had made arrangements with some six thousand gentlemen who in different parts of France and her colonies would devote night after night to the study of meteoric astronomy.

Professor Herschell added some particulars of the work of the committee with regard to the connection between meteors and comets, and stated that the aërolites were stone bodies differing very little from volcanic rocks.

Sir William Thomson said the evidence they had with regard to the mass of comets was altogether negative. There was nothing in observations to justify the assertion of their being so extremely small as sometimes said. It would be interesting to obtain some definite knowledge of the mass of a comet, by comparison with some other body of the solar system. The whole subject still presented great difficulty, and the whole of the wonderful phenomena were not fully explained, but he thought that on the whole they might consider it quite established that the comet's tail was really a train of meteors.

Mr. G J. Symons presented the report of the Rainfall Committee. During the past fifteen years the number of stations has been raised from 241 to nearly 2000.

Relative to the rainfall in Monmouthshire and the Severn Valley on July the 14th, Mr. Symons said the rainfall was simply a mass of vapour that came up from the west, and it commenced at Tenby between midnight and one a.m. on the morning of the 14th July. It travelled at the rate of about 18 miles an hour, and at four p.m. in the same day it passed off by the north coast to Norfolk. As to its breadth it took about 36 hours to pass over any given points. The quantity of water that fell varied very much over the whole country, and was deepest the west side of a line drawn from the Isle of Wight to the Isle of Sheppey, and thence to the north-east. Some stations in Monmouthshire and Glamorganshire had a rainfall of over 3 inches; at fourteen stations the rainfall exceeded 4 inches; at six it was over 5 inches; and at Tintern Abbey, usually considered a dry station, the rainfall was 5·31 in 24 hours. This was followed with storms in which from 2 to 3 inches of rain fell. At Tamunk there was the extraordinary fall of 9½ inches in 8 days, or one-third of the average rainfall for a year.

Professor Hennessy read a paper on "The Influence of the Physical Properties of Water on Climate." The author believes that of all substances largely existing in nature water is the most favourable to the absorption and distribution of solar heat throughout the external coating of the earth.

The same author also read a paper "On the Possible Influence on Climate of the Substitution of Water for Land in Central and Northern Africa."

Captain Abney, R.E., in a paper "On the Increase of Actinism due to Difference of Motive Power in the Electric Light," described the results which had been observed in some experiments made for Government upon magneto-electric machines.

Prof. H. A. Rowland, of Baltimore, described his method of testing the distribution of magnetism in iron bars and also his experiments on the magnetising function of iron, nickel, and cobalt.

The report of the Committee on the Thermal Conductivity of Rocks affirms that quartz is the best and coal the worst conductor.

A paper was contributed by Prof. Osborne Reynolds "On the Force caused by the Communication of Heat between a Surface and a Gas."

The following papers were also read by M. Janssen "On the Eclipse of April 5th, 1875," "On the Actual Position of the Magnetic Equator in the Gulf of Siam and the Gulf of Bengal," "On Mirage at Sea."

CORRESPONDENCE.

AËRIAL LOCOMOTION.

Sir,—I received, some time ago, an article from your valuable paper entitled, "Aërial Locomotion; Pettigrew versus Marey."

I cannot leave unanswered the 20 pages devoted to me; but as I have little taste for polemics, I will not intrude to the same extent on your space. I intend to sum up the chief heads of that accusation, in order to answer them respectively.

1st. The writer states that in a work on the flight of insects, I had pointed out the figure-of-eight track made by their wings, and that, on a demand of Mr. Pettigrew, I have acknowledged that this physiologist had the priority over me relatively to that observation.

2nd. That, later on, "having evidently changed my views," I have declared that, in spite of this conformity, my theory and Mr. Pettigrew's differ materially.

3rd. That, in order to arrive at this demonstration, I had reproduced and altered Mr. Pettigrew's figures.

4th. That, concerning the flight of birds, I had copied Mr. Pettigrew in the same indiscreet manner, to substantiate which the writer of the article accumulates 14 pages of quotations, which, he says, might be more numerous.

I see in this article nothing but the sincere expression of a great love for scientific truth. This feeling finds way in the final sentence in which the author assures that my process "saps the foundation of science."

Before bringing such an accusation it would have been perhaps fair for the critic to be enlightened on the question. If he had consulted Mr. Pettigrew he would certainly have learned that I never accepted his theory on the flight of insects, no more than he accepts mine on the flight of birds. Under these circumstances it was not easy to plagiarise.

My severe accuser may have been misled by the excess of conciseness under which Mr. Pettigrew labours every time he happens to quote my answer to his complaints. In fact he presents it in the following way:—"I have ascertained that in reality Mr. Pettigrew has been before me, and represented in his memoirs the figure-of-8 track made by the wing of the insect, and that the optic method to which I had recourse is almost identical with his. . . . I hasten to satisfy this legitimate demand, and I leave entirely to Mr. Pettigrew the priority over me relatively to the question as restricted."—*Comptus Rendus*, May 16th, 1870, p. 1093.

Now, the suspensive stops which break the quotation stand for the end of the sentence, which runs thus: "But we differ entirely on the interposition of the trajectory seen by us both."

I do not suppose that Mr. Pettigrew has purposely suppressed those last words: perhaps they have escaped him, for I am loth to believe that any author would intentionally mutilate a text; the more so as my sentence quoted in that way has no meaning. What would be the meaning of "leaving the priority as restricted" if no restriction is mentioned?

Then I had not to change my views in order to reject Mr. Pettigrew's theory on the flight of insects. I rejected it as soon as I knew it, and precisely on account of the figure I am accused of having purposely altered.

By referring to page 233 of the Transactions of the Linnean Society, vol. xxvi., and to my work entitled "Animal Mechanism," fig. 86 (page 201 of the English translation), the reader will see that I have very accurately counterdrawn the figure given by Mr. Pettigrew, with arrows showing the direction of the motion. He will see, besides, that the English author expressly states that the wing of the insect is turned completely, and that its "posterior or thin" margin takes the place of the "anterior or thick" margin, *et vice versa*, which implies an active "retournement" of the wing.

But this figure must be looked for in the article of the "Transactions of the L. S.," published before Mr. Pettigrew's complaints and before my answer. It is no more to be found in the posterior publications.

This figure, without doubt, has been lost. It has even been forgotten to such an extent that when Mr. Pettigrew traces afterwards the trajectory of an insect's wing, he points his guiding arrows not in the same direction as formerly, but in the direction according to which I had always pointed them.

With reference to the flight of birds, my accuser piles up quotations. He compares texts, and every time he meets with similar expressions in the English and French books, he raises a cry of plagiarism, as if it were possible to treat of the flight of birds without speaking of wing, child's kite, inclined plane, sculling, &c.

This overflowing copiousness of quotations has the effect, perhaps not intended, of fatiguing the mind and misleading the judgment of the reader. Would it not be much more for the purpose to take Mr. Pettigrew's own opinions on the debate?

Mr. Pettigrew, in his last work ("The Animal Locomotion"), devotes 10 pages to impugn my theory on the flight of birds, and a special chapter to show to what extent his own theory differs from it. This work of Mr. Pettigrew, as well as my book entitled "Animal Mechanism," having been respectively translated in both languages, every one can compare them, and by so doing, will ascertain that two authors could not easily have treated the same subject with more widely dissimilar methods and arrived at more different conclusions.

But those who have only read the article in the "Quarterly Journal" may form an estimate of me which I am anxious to correct.—Believe me, dear sir, yours very respectfully,

MAREY.

Professeur au College de France.

PROGRESS IN SCIENCE.

MINING.

From the Annual Reports of the Inspectors of Mines, issued during the past quarter, it appears that in the year 1874 there were 4332 mines working under the Coal Mines Regulation Act. The number of persons employed was 537,178 in Great Britain and 1651 in Ireland. The total number of lives lost in our coal and iron mines was 1056, as against 1069 in the previous year. In our metalliferous mines there were only 103 deaths from accidents.

A valuable paper by Mr. Handel Cossham, Mr. Wethered, and Mr. Saise, descriptive of a part of the Bristol coal-field, was read before the Geological Section of the British Association, and has since been published, with illustrations, in the "Colliery Guardian."

It is proposed by Mr. A. B. Boullenot, of Paris, that safety lamps in fiery pits should be furnished with air introduced entirely from outside the mine. To this end compressed air is forced from an air-pump at the surface down a system of pipes leading to the lamp. The lamp itself is of improved construction, and specially adapted for receiving compressed air.

An interesting paper on the history of the methods of draining mines by non-rotating steam appliances, by Mr. Stephan Holman, has been published in the "Transactions of the Chesterfield and Derbyshire Institute of Mining Engineers."

The gold districts of the Province of Otago in New Zealand have been reported on by Mr. G. F. Ulrich. The observations were made during a tour of inspection in the early part of this year, and refer not only to the auriferous quartz-reefs and crushing machinery, but also to the occurrence of copper ore, cinnabar, antimonite, and brown coal. Appended to the Report is a description of the German Treppenrost or step-furnace for the combination of brown coal.

Gold-mining in Japan has been the subject of a Report by Mr. H. S. Munroe, of the Imperial College of Tokai. The richest of these gold deposits are those at Toshibetsu, which are worked in a primitive manner by the Japanese; but even these are extremely poor, and would probably not repay the cost of introducing improved methods of working.

Mr. Mark Fryar his issued a Report from Moulmein, dated last May, in which he describes several mineral localities in Burma. Gold-mining is carried on at Shwe-gyeen, and iron ores appear to be generally distributed, but are worked only on a small scale and in primitive fashion.

It may be worth noting that the celebrated Adalbert shaft of the silver-lead mines of Pribram in Bohemia, has just reached the extraordinary depth of 1000 metres. The events was celebrated by festivities on the 13th, 14th, and 15th of September.

METALLURGY.

At the Annual Provincial Meeting of the Iron and Steel Institute, held this year at Manchester under the presidentship of Mr. Menelaus, a paper "On the Use of Caustic Lime in the Blast-Furnace" was read by Mr. I. Lowthian Bell, M.P. The author described in detail some researches carried out at the Clarence Works with the view of determining what advantage, if any, results from calcining the limestone before using it as a flux. In a furnace 48 feet high, of a capacity of 6000 cubic feet, and with a make of about 200 tons per week, the saving of fuel effected was only insignificant, but the yield of iron from Cleveland ores was increased, and the quality of the metal was improved. In a furnace of better construction, 80 feet high, holding 20,000 cubic feet, and yielding 350 tons weekly, there appeared to be absolutely no advantage in employing calcined instead of raw limestone. It appears, however, that in none of the trials was more than about one-half of the carbonic anhydride expelled from the stone.

Some improvements in the form of moulds for casting ingots of steel have been effected by Mr. W. Hackney, who explained to the Institute the construction of these moulds. Being subject to very sudden and violent alternations of temperature, the ordinary moulds frequently crack; but in Mr. Hackney's design the thickness of metal at different parts of the circumference of the mould is so adjusted that the expansion when heated is pretty equal all round, and the cracking is thus to a large extent prevented.

An improved form of hearth lately put in at one of the blast-furnaces of the Tees Iron Works was described to the Institute by Mr. Charles Wood, whose methods of utilising slag are now well known. Mr. Wood's hearth combines the closed-hearth system with an open fore-part, and a new water-plate arrangement over which the slag is drawn, and by which it is prevented from destroying the brick work or fire-clay through which it issues.

Price's Patent Retort Furnace, which was brought before the Institute by Mr. Lowthian Bell, is an arrangement for avoiding the loss of heat which occurs in the gas-producers of the regenerative furnace. Several of these retort furnaces have for some time been in use at Woolwich.

Certain improvements in rotatory puddling-furnaces have recently been effected by Messrs. E. A. and J. A. Jones, of Middlesbro'. The improvements relate chiefly to the means of admitting and expelling water from the casing of the furnace.

Some experiments on puddling by the aid of a blast have been made at the Bull Bridge Iron Works, near Wolverhampton, and appear to be of some importance. The blast is injected through four tuyères at the top of the furnace, and by impinging on the flame, as soon as it has come over the fire-bridge, produces an intense heat, which hastens the puddling and is said to improve the character of the metal.

In blowing out a blast-furnace in the Middlesbro' district some crystalline products were found in the upper part of the "dead horse," and these have been analysed by Mr. G. Johnston, of Leeds, who has communicated the analyses to the "Chemical News." The mass of slag and metal under the hearth had probably been exposed for 10 or 12 years to a temperature not much below the melting-point of cast-iron. The crystals found in this mass are octahedral in form, and may be resolved into two portions, one part being malleable and the other easily pulverised. A sample of the latter yielded as much as 29·58 per cent of graphitic carbon.

M. Boussingault's "Etudes sur la transformation du fer en acier par la Cementation" will be found in a recent number of the "Annales de Chimie." The objects of his experiments were to determine how long the iron and carbon are in contact at a red heat during the process of cementation; what is the temperature of the interior of the chests at different stages of the process; and what the nature and quantity of the substances acquired or lost during the changes effected by cementation.

It seems likely that metallurgists may soon be able to use petroleum as a fuel, if reliance can be placed on what has been called "A New System of Oil Metallurgy." Experiments made in New Jersey by Dr. Eames have shown, it is said, that petroleum may advantageously be used in the re-heating furnace for iron. The petroleum in the Eames furnace is converted into vapour in the "generator," where it drips from shelf to shelf, and during its flow meets a slow opposing current of steam. The mixed vapours pass into a chamber where they are brought in contact with a blast of air, and combustion consequently effected.

The metallurgist, not less than the physicist, is interested in Mr. W. C. Roberts's recent researches on certain alloys of silver and copper which have been brought before the Royal Society. These silver-copper alloys possess such molecular mobility that it is difficult to obtain an ingot of homogeneous composition. The melting-points of a series of alloys of silver and copper are represented graphically, and the curve exhibits a somewhat rapid fall from pure silver to the alloy employed for our silver coinage, which contains 925 parts of silver in 1000 of the alloy, and corresponds approximately to the formula Ag_7Cu. The alloy of lowest melting-point is represented by the simple expression AgCu. Liquidation appears to result from unequal cooling of the molten mass, and is modified if the cooling be retarded. The experiments made on cubes of various alloys showed that the molecular arrangement is largely dependent on the rate of cooling.

Under the name of *Dysiot* a new alloy has been introduced in Germany. Its analysis has yielded, copper, 62·30; lead, 17·75; tin, 10·42; zinc, 9·2; iron, traces.

According to Mr. Sergius Kern the chrome-iron ore of the Ural mountains has been used in the preparation of a chrome-iron alloy, which possesses a remarkable degree of hardness, and may be used as a substitute for spiegeleisen in the preparation of steel by the Siemens process.

MICROSCOPY.—Mr. H. J. Slack[*] supplies the following valuable information respecting the use of Mr. Wenham's "Reflex Illuminator."[†] "If Mr. Wenham's Reflex Illuminator is used under the circumstances for which he especially contrived it little difficulty will be found with suitable objects. The light, as he explained, penetrates only where the object makes a new surface on the slide, and 'acts,' to use one of his familiar phrases, 'like a hole in a dark lantern.'" The effect is so admirable upon many objects, such as scales of insects, certain micro-fungi, minute algæ, desmids, diatoms, &c., that every one who has successfully tried it must wish to add to its range of utility, and this may be easily done. It will be found that most balsamed objects, and many in which the covering glass lies very close to the slide, give with it so much false light when ordinary objectives are employed that the result is very unsatisfactory. This false light will be found in many cases so oblique that it can be got rid of by using an objective with a small angle, or temporarily reducing the angle of an ordinary high power by a movable stop. For example, a slide of *Surirella gemma* and this illuminator exhibited no false light with a glass of about 7°; some, but not much, with a fine one-fourth made on Mr. Wenham's new formula, and having an angle of 150°; too much to be endurable with Powell and Lealand's immersion one-eighth full aperture; and none with the same glass and with a stop limiting the rays admitted to about 90°. Many slides of butterfly and other scales taken at random from a cabinet become manageable with reduced apertures, and the effects, when the plan succeeds, are very curious, beautiful, and instructive. Mr. Wenham has alluded to the changed aspects obtained by rotating the apparatus when employed upon the so-called Podura scale *Lepidocyrtus curvicollis*, and similar observations may be made with regard to Lepisma scales, and those of various insects allied to Podura. Indeed it is not prudent to pronounce an opinion upon any scale of difficulty until this method has been tried and all the aspects it produces considered in their mutual relations. It is by no means intended to advise microscopists against the use of this apparatus with large-angled glasses upon objects mounted so as to be fit for it; but when slides fail the observer is recommended not to abandon the plan, but to reduce the angle of the glass and try again, and with good chances of success. The apparatus has a remarkable power of increasing both the penetration and resolution of good objectives.

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[*] Paper read before Royal Microscopical Society, 2nd June, 1875.

[†] "Quarterly Journal of Science," vol. ii., p. 400.

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